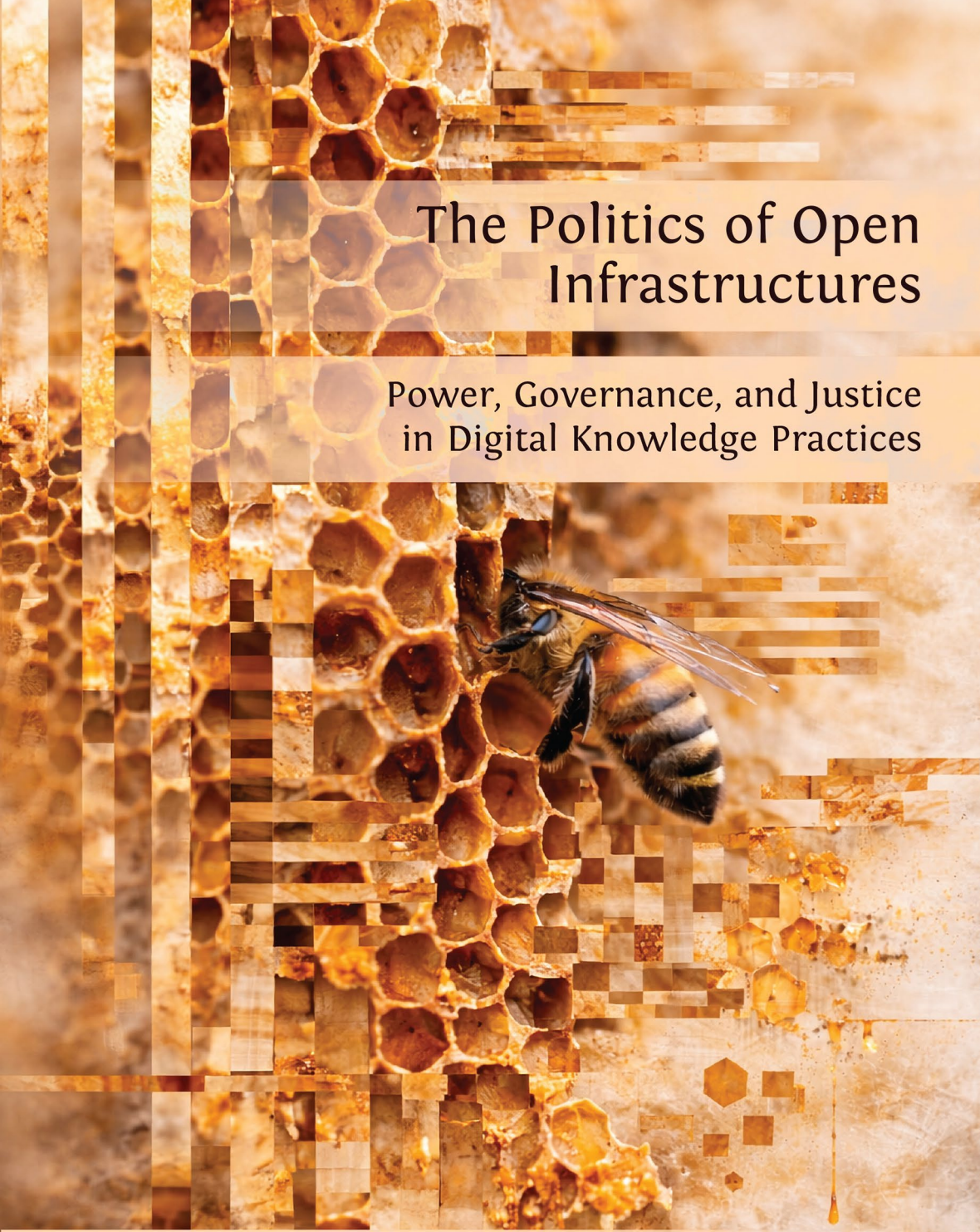
The Politics of Open Infrastructures

Power, Governance, and Justice in Digital Knowledge Practices



Edited by Katja Mayer, Astrid Mager and Renée Ridgway

THE POLITICS OF OPEN INFRASTRUCTURES

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Power, Governance, and Justice in Digital Knowledge Practices

Katja Mayer, Astrid Mager, and Renée Ridgway

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Introduction: The Politics of Open Digital Knowledge Infrastructures

Astrid Mager, Katja Mayer, and Renée Ridgway

In the mid-2020s, a series of infrastructural incidents made visible how deeply public authority, communication, and knowledge circulation have become entangled with privately operated digital infrastructures. Large-scale outages of cloud, identity, and content delivery services in 2024 and 2025 disrupted communication in hospitals, airports, courts, universities, and government administrations across multiple world regions. One prominent example is the 'largest outage in history' (Milmo et al. 2024) that was caused by the American cybersecurity company CrowdStrike, whose faulty update led to widespread problems with Microsoft Windows computers running the proprietary software worldwide. Patient records became temporarily inaccessible, air traffic systems reverted to manual procedures, and public communication channels failed not because of local malfunction, but because shared infrastructural layers ceased to operate. What appeared as technical disruption revealed a structural condition: essential public functions depended on a small number of globally integrated service providers. At the same time, disruptions did not only occur through technical failures. In a widely discussed case, access to email and cloud services used by a judge investigating war crimes of US allies at the International Criminal Court in The Hague was suspended by Microsoft following geopolitical pressure from the US (Lin 2025). In this widely discussed case, no infrastructure broke down. Instead, access to communication and institutional memory was withdrawn through contractual and technical means. Judicial communication, legal coordination, and the circulation of authoritative knowledge were directly

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affected by decisions taken outside the jurisdiction of the institution itself. This incident raises fundamental questions about where sovereignty resides when core communicative infrastructures of public authority are privately owned and globally governed.

As a response to the vulnerabilities made visible in recent years, calls for digital sovereignty have moved beyond narrow circles of activist communities and gained ground in policy domains across the globe, especially in Europe. The Summit on European Digital Sovereignty gathered more than nine hundred representatives from policy, industry, research, and civil society in Berlin and is just one example of this larger trend (November 2025).[1] Policy makers and regulators have come to recognise that interoperable, collectively governed technical systems may offer pathways to infrastructural autonomy by reducing dependencies on dominant platform providers from the US or China, and embedding alternative values into the architectures that mediate communication, commerce, and public administration. Federated protocols, open standards, and commons-based software are no longer confined to countercultural milieus; increasingly, they have entered the vocabulary of statecraft and industrial strategy. This political attention, however, remains structurally fragile. Public investment in open infrastructures is episodic and undersized in comparison to the capital concentrated in proprietary ecosystems. Political will, where it exists, tends to be orientated towards short funding cycles and project-based interventions ill-suited to the long temporal horizons that infrastructure maintenance demands. The rhetorical embrace of openness thus coexists with institutional arrangements that continually reproduce its material fragility.

This tension sets the stage for a central problem addressed throughout this book: openness is widely invoked as a value, but rarely treated as an infrastructural achievement that requires sustained governance, resourcing, and collective stewardship. In much policy discourse, 'open' functions as a static attribute such as a licensing category, transparency claim, or formal compliance marker, rather than a dynamic socio-technical accomplishment requiring continuous maintenance, care and solidarity-oriented coordination. Such framings obscure the

1 See https://www.bundesregierung.de/breg-de/aktuelles/summit-on-european-digital-sovereignty-delivers-landmark-commitments-for-a-more-competitive-and-sovereign-europe-2394368

infrastructural work through which openness is created and preserved, including upkeep labour, institutional alignment, and the negotiation of responsibilities across heterogeneous actors. When openness is treated as a formal property rather than an ongoing practice, it easily becomes entangled with zero-sum imaginaries. Openness then appears as a loss of control or competitive advantage, rendering commons-based approaches politically fragile and economically suspect. What is overlooked is that openness does not negate value creation, but redistributes it across time, actors, and institutions. Without attention to this processual and relational character, strategies aimed at digital sovereignty risk reproducing the very logics of enclosure and extraction they seek to counter, while abandoning collaborative and distributed modes of infrastructural innovation.

Analytical Foundations: Knowledge, Infrastructure, and Politics

In this book, we approach openness through the combined lens of knowledge, infrastructure, and politics—understanding openness as a contested mode through which their relations are organised. Openness, in this context, refers not primarily to transparency or access alone, but to infrastructural arrangements based on open standards, shared governance, and the possibility of collective participation in the design, maintenance, and oversight of the systems that organise knowledge circulation. Building on science and technology studies (STS), and infrastructure studies most importantly (Star and Ruhleder 1996; Star 1999; Edwards et al. 2009; Bowker and Star 2000; Bowker et al. 2010; Borgman et al. 2013), we perceive knowledge not as abstract information, but as something produced, circulated, and stabilised through material and institutional arrangements. We conceptualise infrastructure as the socio-technical systems, standards, organisation, and practices that make such knowledge durable and shareable over time. Politics, finally, denotes the power relations, value commitments, and governance decisions that shape how infrastructures are designed, maintained, and made accessible, and for whom. Openness, in this perspective, is neither a fixed property nor a purely normative ideal, but an ongoing socio-technical accomplishment that structures inclusion and exclusion, participation and control, across

knowledge practices and infrastructural arrangements.

To attract contributions from different empirical contexts, cultural backgrounds, and situated perspectives (Haraway 1988), we posed a central guiding question in our Call for Contributions: 'How can open digital knowledge infrastructures redistribute power and drive social change within the political, technological and cultural fabrics of society'? We invited authors to engage with this question by positioning their work at the intersection of knowledge practices, infrastructural arrangements, and political dynamics, with openness understood as a contested and ongoing accomplishment rather than a normative given. This approach resulted in a rich compilation of empirical analyses, research notes, commentaries, as well as calls for action that all engage with open digital knowledge infrastructures as living objects, continuous processes, and communities of practice rather than technical entities or consumer products. Combining concepts from diverse disciplines including STS-oriented infrastructure studies, critical data studies, organisational studies, new media scholarship, epistemic justice approaches, arts-based research, and critical making, the book's chapters collectively paint a colourful picture of how knowledge production and circulation are shaped through infrastructural arrangements that are deeply embedded in social, cultural, economic, and political contexts. Despite their different empirical sites, methodological approaches, and cultural situatedness, all chapters conceptualise—and investigate—digital infrastructures as highly social and political endeavours that require careful thought and action, and whose openness must be actively organised, governed, and sustained. What unites these diverse cases is that they enable knowledge production and circulation through socio-technical arrangements whose openness is always partial, negotiated, and politically contested.

Crosscutting Themes: Socio-technical Complexities, Platformisation, and Infrastructural Politics

To make the diversity of case studies analytically productive, this book is structured around three interrelated aspects that cut across the contributions. First, the socio-technical complexities foreground the relational work, coordination, and care through which knowledge infrastructures are built and maintained. Second, the platformisation of infrastructures examines how open systems become entangled

with platform-based ecosystems, corporate power, and logics of accumulation. Third, the politics of infrastructures addresses how struggles over openness, access, governance, and resourcing are inseparable from broader questions of power, public value, and social order. Together, these aspects provide a shared analytical vocabulary for examining how openness operates across knowledge practices and infrastructural arrangements.

Socio-technical Complexities

Ethnographic studies on large-scale knowledge infrastructures have long emphasised that infrastructure building is a complex process involving not only technical, but also social and organisational entities (Bowker and Star 2000). Star (1999: 380) famously described infrastructure 'as part of human organisation' drawing attention to the often invisible, backstage work practices, conventions, and forms of coordination that allow infrastructures to function. From this perspective, infrastructures are better understood as relationships rather than a stable, technical 'thing' (Bateson 1978: 249). Socio-technical complexities arise from the multi-layered and distributed nature of infrastructure work. Building and maintaining infrastructures involves heterogeneous forms of labour, including hardware and software engineering, standard-setting, data curation, and the integration of new technologies into existing organisational routines, much of which remains invisible in everyday use (Star 1999). Infrastructure building therefore takes time (Karasti et al. 2010) and requires continuous negotiation and adjustment across actors, sites, and institutional contexts. As Star put it:

> Because infrastructure is big, layered, and complex, and because it means different things locally, it is never changed from above. Changes take time and negotiation, and adjustment with other aspects of the systems are involved. Nobody is really in charge of infrastructure (1999: 382).

Responsibility is thus distributed, control is partial, and change is incremental. Such socio-technical complexities are particularly salient for open digital knowledge infrastructures. Infrastructures are not 'naturally' open. They become open through historically grown political, technical, and economic dynamics. Large technical systems, ranging from electric power grids and air traffic control to transoceanic cables, data centres, and radiation-emitting technologies,

are typically centrally designed and controlled, exhibiting qualities of ubiquity, reliability, and durability (Plantin et al. 2016; Mukherjee 2020; Starosielski 2015). Their complexities often become visible only in moments of failure, breakdown, or scaling, highlighting the importance of maintenance, compatibility, and standardisation (Star 1999).

Early digital networks differed in this respect. While closed systems relied on network effects and centralised control to scale globally, early internet protocols, software standards, and data formats depended on openness to function across institutional, national, and organisational boundaries. Openness was therefore not primarily a normative commitment, but a functional condition for interoperability and coordination at scale. A number of chapters in this volume, however, illustrate how power relations and cultural barriers undermine internet governance processes, the politics of open code, and how the openness of 'the internet' has always been partial and situated rather than universal, for example. This research foregrounds the socio-technical complexities of infrastructure building and maintenance, revealing why abstract calls for openness, transparency, or digital sovereignty often underestimate the work, coordination, and institutional transformation required to make openness function in practice.

Platformisation of Infrastructures

While infrastructure studies foreground the distributed and relational character of infrastructural work, more recent scholarship has shown how these arrangements are increasingly reorganised through processes of platformisation (Helmond 2015; Plantin et al. 2016; van Dijck et al. 2018). Platforms do not merely operate on top of infrastructures. They increasingly function as infrastructural environments that mediate access, authentication, storage, and circulation, embedding themselves deeply into the conditions under which communication and knowledge are produced and governed. This research highlights the dynamic character of infrastructures, which are in constant adaptation to the other components' changes and can splinter, break up, or even die (Plantin et al. 2016: 295). Van Dijck (2020) describes how corporate platforms accumulate infrastructural power in digital ecosystems by installing

themselves as necessary gateways to online services. Platformisation reshapes these ecosystems by centralising control over key points of coordination, such as interfaces, standards, metrics, and data flows. This dynamic has been described as the 'infrastructuralization of platforms' and, conversely, the 'platformization of infrastructures' (Plantin et al. 2016). As platforms become indispensable intermediaries, they acquire the capacity to shape what forms of communication are possible, visible, or actionable.

Platformisation introduces new forms of asymmetry into already complex infrastructural arrangements. As van Dijck and colleagues argue, platforms increasingly govern public and private domains by defining the rules of participation, circulation, and value creation, while remaining formally private and commercially oriented (van Dijck et al. 2018; van Dijck 2020). When platforms attain critical infrastructural status for their publics, decisions about access, continuity of service, or data retention take on quasi sovereign effects, enacted through contractual and technical mechanisms rather than public law. This reconfiguration is particularly consequential for open digital knowledge infrastructures, which often rely on platform services for hosting, dissemination, metrics, and interoperability.

The growing policy interest in digital public infrastructures reflects attempts to counter these dependencies, yet it also illustrates the ambivalence of platformisation. The concept of infrastructure as a public good has gained considerable policy traction, particularly within EU institutions and the Global South, yet its relationship to open knowledge infrastructures is ambiguous at best. Critics argue that the discourse on digital public infrastructures has been captured by techno-solutionist framings that treat social problems as technical deficits solvable through corporate 'stacks,' channelling public resources toward US-based cloud and AI corporations rather than genuinely public alternatives (Brennan et al. 2025). In the scholarly domain, data governance frameworks such as the FAIR principles for data management (Wilkinson et al. 2016) and the CARE principles for Indigenous data governance (Carroll et al. 2020)[2] articulate important normative responses, but remain limited

2 The FAIR principles define standards for data management that aim to make data Findable, Accessible, Interoperable, and Reusable, primarily by focusing on technical metadata, standardisation, and machine readability in order to enhance data reuse

if they do not address the infrastructural conditions under which data, communication, and knowledge circulate, as a number of chapters discuss in this volume. Taken together, this perspective shows that platformisation does not simply threaten openness from the outside. It actively reshapes the infrastructural conditions under which openness, sovereignty, and public value are negotiated, helping to explain why open digital knowledge infrastructures remain fragile under conditions of entrenched platform power.

Infrastructural Politics

The notion of politics that we adopt in this book highlights that open infrastructures are not neutral, technical artefacts but sites where values, power relations, and forms of social order are materially inscribed and enacted (Winner 1980). We therefore emphasise the role of infrastructures in creating and reinforcing social order, and vice versa, where decisions about infrastructure development and maintenance can have significant implications for social inclusion, access to resources, and the distribution of power. A political lens on infrastructural openness thus shifts the focus from declared values to sites of decision-making. It asks who can decide how infrastructures operate, who bears responsibility when they fail, and under what conditions access can be granted, limited, or withdrawn. In this sense, openness becomes a matter of equity and thus of governance and authority, rather than a technical feature or ethical aspiration, since the formal availability of open infrastructures does not by itself secure meaningful access, use, or benefit across differently positioned actors (Okune et al. 2019; Bezuidenhout 2025).

Historical studies of infrastructure illustrate that such political dynamics are not new. Critical infrastructures such as railways were deeply embedded in projects of state-building, standardisation, and the constitution of publics. As with the fibre optic cables of today that follow old undersea telegraph lines, the analogy with railways

in research and innovation contexts. The CARE principles complement FAIR by foregrounding ethical and political dimensions of data governance, especially for Indigenous and marginalised communities. CARE emphasises Collective benefit, Authority to control, Responsibility, and Ethics, highlighting questions of power, consent, and stewardship that are largely absent from purely technical approaches to openness.

is illustrative not simply for its materiality but for its embeddedness in government structures, standardisation, and public utilities. Successful 'system builders' of the past were those who managed to successfully connect their inventions to existing infrastructures, legal systems, and socio-political contexts (Hughes 1979). Railways, like other critical infrastructures, were described as mirroring the 'modern infrastructural ideal' (Graham and Marvin 2001) that originated around the middle of the nineteenth century—an ideal of cities being responsible for providing certain services such as roads, emergency services, and public transport to all citizens (Plantin et al. 2016). From the late twentieth century onwards, however, this ideal was increasingly undermined by processes of deregulation and privatisation, resulting in more fragmented, uneven, and market oriented infrastructural landscapes (Plantin et al. 2016).

A similar trajectory can be observed in the comparatively short history of the internet, as some of the following chapters will show. While the first twenty years of internet history (1960s-1980s) were described as embodying the modern industrial ideal with heavy government investments and the impetus of providing citizens with network access as a public good, that model was abandoned in the late 1980s with the rise of neoliberalism (Abbate 1999; Lee and Schmidt 2018). The process of deregulation, privatisation, and splintering of the internet infrastructure and the rise of ubiquitous mobile computing created an environment in which corporate platforms achieved enormous scales (Plantin et al. 2016). Open digital infrastructures today operate within this political environment, which explains persistent tensions around corporate capture, power asymmetries in standardisation, and the privatisation of governmental and research infrastructures.

Politics, however, does not only act through corporate power, policy, or law, but also through mundane decisions about what data are worth maintaining, what gets fixed, what is allowed to decay, and who is expected to absorb failure. Rather than treating data as stable inputs or outputs of infrastructural systems, it is worth studying how data is continuously produced, repaired, classified, and maintained through everyday organisational practices. Zakharova and Jarke (2024: 5) conceptualise data work as 'care work that sustains and enables the production, processing, circulation, and use of data.' In everyday

organisational practice, Jarke and Büchner (2024) argue that 'data care arrangements are configured through the ascription of values to (specific) data sets *and* the work of generating, maintaining, and repairing data' (Jarke and Büchner 2024: 704, italics in original). Data work provides a valuable entry point for analysing how political choices about value, priority, and responsibility are enacted through mundane infrastructural practices rather than formal regulation alone. Numerous case studies in this book underline the political nature of data work and link it to data governance frameworks and epistemic justice approaches in the context of global publishing, artistic research projects or citizen science in the Global South.

Book Outline: From the Early Internet to the Future of Infrastructuring

Taken together, the three analytical lenses developed in this introduction clarify why openness in digital knowledge infrastructures cannot be understood from a single vantage point. Combined, these lenses—which are more or less present in all of the following chapters—allow the book to discuss openness not just as a normative ideal or technical feature, but as a fragile and contested outcome of infrastructural arrangements through which knowledge is produced, circulated, and governed. The main part of the book is made up of in-depth empirical case studies, complemented by shorter commentaries, an interview and research notes, culminating in calls for action. Taken together, the book moves from the partial openness of early internet standards and free and open-source software, through contested practices of opening government data and public infrastructures, to struggles over inclusion and governance in scholarly and cultural knowledge infrastructures. This is followed by community-driven experiments in care, repair, and alternative openness, and concludes with forward-looking contributions on how to keep infrastructures open for research, how to fund infrastructures as digital commons, and how to mobilise open infrastructures for democratic resilience and economic sovereignty. All contributions are clustered in five thematic sections that we briefly discuss now.

1. Early Days of Internet Openness

The first section revisits the early history of the internet to show that openness was never universal, but always partial, situated, and contested. It is concerned with processes of internet standardisation, free and open-source developments, and ways in which openness was unevenly distributed, enabling participation for some groups while remaining closed to others. Corinne Cath examines the cultural governance of open internet standards and the limits of formal inclusivity in the Internet Engineering Task Force (IETF). Renée Ridgway traces the political and ethical tensions and values shaping free and open-source software as an open infrastructure. In his commentary, Niels ten Oever argues that Internet openness has always been selective, determined by the interests of specific groups rather than universal publics.

2. Opening Government Data Infrastructures

The second section focuses on government data and public infrastructures, highlighting the labour, institutional cultures, and political constraints shaping openness in practice. It explores various degrees of openness of government infrastructures by discussing practices of opening up government data in Austria, smart waste infrastructures in Poland, and the call for digital sovereignty in the European Union. Astrid Mager analyses three Austrian initiatives of opening up government data in the context of the data welfare state and bureaucratic secrecy. Celina Strzelecka examines smart waste infrastructures in Poland, showing how data driven systems reconfigure responsibility and dependency rather than delivering transparency by default. Francesca Musiani situates her commentary within European debates on digital sovereignty and shows how federated infrastructures transform alternative decentralisation into a contested tool of state governance.

3. Inclusive Governance of Digital Knowledge Infrastructures

This section addresses the governance of scholarly and cultural knowledge infrastructures, with a focus on openness, inclusion, and epistemic justice. It brings together studies that examine how

openness is organised and contested across different infrastructures in research and the arts, including a platform ecosystem for open scholarly communication, a directory for open access journals, research infrastructures analysed through the lens of openness paradoxes, and an archival infrastructure for knowledge sharing in artistic research. Simon Dumas Primbault analyses scholarly communication platforms as governed ecosystems through a case study of OpenEdition. Ivonne Lujano Vilchis, Katrine Sundsbø, Ina Smith, and Joanna Ball examine the Directory of Open Access Journals (DOAJ) as a global infrastructure negotiating inclusivity through standards and classification work. Katja Mayer explores how openness governs scholarly infrastructures while reinforcing existing power imbalances. A research note by Lucie Kolb and Lara Kothe reflects on building an open research database in the arts through feminist and anti-colonial perspectives on FAIR and CARE.

4. Community-driven Infrastructures of Care and Repair

The fourth section foregrounds counter-cultural and community-based infrastructures that experiment with alternative modes of openness, including a citizen science project indexing Andean potatoes, a grassroot community network in Italy, computational repair in the Netherlands and Ghana, to open AI image generation assemblages. Julio Sebastián Zárate Vásquez and Jason A. Delborne examine citizen science and Indigenous data governance in Andean potato conservation. Stefano Crabu analyses grassroots community networks as sites where openness is enacted through maintenance, governance, and care. Cyrus Khalatbari compares computational repair practices in Amsterdam and Accra, highlighting low tech and maintenance-driven alternatives. Nicolas Malevé discusses open AI image generation projects as infrastructural variations operating within, rather than outside of, corporate ecosystems.

5. Infrastructuring Openness in the Future

The final section explores forward-looking questions of infrastructural sustainability, governance, and resilience. An interview with Annalisa Pelizza reflects on how to keep digital knowledge infrastructures open as communities of practice. In her commentary, Katharina Meyer conceptualises resourcing as infrastructural work and argues for durable

funding architectures for the digital commons. Leonhard Dobusch and Maximilian Heimstädt conclude the volume with six theses on open digital infrastructures as foundations for democratic resilience and economic sovereignty.

Concluding Remarks and Outlook

At the beginning of the introduction, we discussed open digital knowledge infrastructures through three interrelated analytical lenses: socio-technical complexity, platformisation, and infrastructural politics. Rather than treating these as separate domains, the contributions in this book demonstrate how they intersect across diverse empirical contexts and infrastructural sites. From early internet standards and free and open-source software to government data systems, scholarly communication platforms, community networks, and emerging AI assemblages, the chapters show that openness is always produced through complex socio-technical arrangements, increasingly shaped by platform logics, and continuously negotiated as a matter of governance and power. Reading across the five sections of the book, these lenses reveal three recurring patterns: the precarious socio-technical labour and coordination work required to sustain openness, the fragility of open infrastructures tightly intertwined with platformisation, as well as the situatedness of digital knowledge infrastructures linked to both political and epistemic implications.

The first pattern points us to the precarious socio-technical labour and coordination work required to develop, maintain, and govern open digital knowledge infrastructures and make them sustainable in the long run. Many core digital infrastructures emerged in and around publicly funded research, where norms of sharing, reproducibility, and peer verification favoured open protocols, open code, and later open data and publications, often relying on free labour, above and beyond academic payment. The opening of government infrastructures involves a range of different types of data work including standard setting, formatting, cleaning, as well as organisational communication and coordination —sometimes hampered by a bureaucratic culture of secrecy rather than openness. While such work is needed for all infrastructures, open infrastructures are often characterised by persistent shortages

of resources, labour, and infrastructural power, which constrain their ability to meet the organisational and technical requirements necessary to sustain openness over time. As Meyer (Chapter 16) argues through the notion of 'resourcing as infrastructuring,' what is ultimately at stake is not merely the viability of individual projects, but the long-term sustainability of the digital commons itself. What the various chapters in this book show is that socio-technical complexity should thus not be seen as a background condition but rather as the terrain on which openness succeeds or fails because openness depends on labour-intensive coordination, maintenance, standardisation, and data care rather than verbal declaration—action rather than words.

The second pattern reveals the fragility of open infrastructures tightly intertwined with the increasing platformisation of infrastructures that reorganises the conditions of openness by centralising control over hosting, authentication, interfaces, and metrics, along with making withdrawal and dependency governable through contracts and computation. Besides precarious labour conditions, historically grown power imbalances and systemic biases in institutions threaten to undermine normative ideals, or rhetoric, of openness and digital sovereignty. Practical constraints such as external funding structures or top-down governance frameworks additionally prevent meaningful participation and processual openness. Several chapters in this book hence challenge binary understandings of openness versus closedness by demonstrating that open infrastructures also persist through graduated forms of openness shaped by infrastructural design choices and political compromise (Chapter 4, Chapter 14). They point us to different degrees of openness, infrastructural arrangements, and compromises or 'continuous variations' rather than radical disruptions, as Malevé has put it in the context of computational practices of appropriation (Chapter 14). Embracing infrastructural tensions and ambiguity could thus be seen as an essential part of strengthening fragile open digital knowledge infrastructures and fostering them within the wider trends of platformisation and cloud computing.

The third and final pattern refers to the situatedness of digital knowledge infrastructures that not only links to infrastructural politics and governance, but also to fundamental questions of epistemic justice. Contrary to abstract notions of openness, participation, and sovereignty, the richness of case studies assembled in this book shows how culturally

and politically situated and context-driven open digital knowledge infrastructures unfold in messy, real-world contexts. It illustrates how openness has been mobilised in distinctive ways and in different moments of time: as a governance strategy to avoid state monopolies and create public value, to counter economic power and concentration, and to technically undermine centralisation and single points of failure. It further shows how carefully abstract ideals of openness and participation need to be translated into culturally diverse social practices, organisational structures, and knowledge cultures to prevent power asymmetries and epistemic injustices they hope to eliminate. A number of chapters critically engage with the FAIR and CARE data governance principles and show how to practically implement them as meaningful instruments of inclusion rather than mere lip service (see Chapter 8; Chapter 9; Chapter 10, Chapter 11). Otherwise, openness runs the risk of becoming an act of window dressing rather than an infrastructural reality; similar to purposes of 'ethics washing' in the context of AI (van Maanen 2022; Mager et al. 2025).

The three patterns mapped out above are nowhere more visible than in the current (and future) battlefield of AI developments. The proliferation of nominally open foundation models has been accompanied by new forms of structural closure: model weights may be released while control over training corpora, computational infrastructure, and downstream ecosystems remains concentrated among a narrow set of actors. Such configurations capture the reputational capital of openness without distributing its substantive affordances: a dynamic that was repeatedly termed 'open-washing' by tech companies using open-source models and code (Liesenfeld and Dingemanse 2024). Simultaneously, the extreme capital intensity of large-scale model development accelerates concentration, foreclosing the distributed, community-governed trajectories that earlier waves of open-source software enabled. Based on interviews with developers, Ridgway proposes that free and open-source software is nowadays considered an open infrastructure, which is essential for society, yet it also needs to be regulated by society, not corporations (Chapter 2). The AI field currently illustrates that openness must be defended infrastructurally: through investment in shared resources, governance arrangements that distribute power, and institutional designs capable of resisting capture. The politics of open infrastructure, in other words, is not merely a question of licensing or

disclosure but of the material and institutional conditions under which genuine openness can be produced and sustained.

This book argues that openness, if it is to function as more than rhetoric, must be treated as an infrastructural project: one that requires sustained governance, shared responsibility, and long-term resourcing rather than temporary interventions or symbolic commitments. It shows that open digital knowledge infrastructures do not automatically counter concentration and dependency, but that concrete pathways are needed for redistributing control, enabling participation, and anchoring knowledge circulation in the public interest, such as those discussed in the following chapters. In an era in which cloud platforms, data-driven systems, and AI increasingly shape the horizons of public authority, the question is no longer whether openness is desirable, but under what infrastructural conditions it can be made durable. This volume is concerned with precisely those conditions. It provides a rich repertoire of suggestions on how to escape rhetorical attempts of 'open-washing' and how to foster infrastructural openness rooted in meaningful participation, mutual engagement, and epistemic justice.

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I. EARLY DAYS OF INTERNET OPENNESS

1. Send Conservatively, Accept Liberally: Cultural Governance of Open Internet Standards

Corinne Cath

1. Introduction: Rejecting Kings, Presidents, and Voting

In 1992, as the internet expanded beyond its academic origins, computer scientist David Clark articulated the operating principle of the Internet Engineering Task Force (IETF): 'We reject kings, presidents, and voting. We believe in rough consensus and running code' (Clark 1992). This statement, delivered at a time when the internet was rapidly evolving from a government-academic project to a global commercial network, continues to reflect the central approach of the IETF today. The IETF is a technical community responsible for building key internet infrastructure, where decisions are based on engineering solutions rather than formal voting procedures.

Almost four decades after its founding, the IETF continues to serve as one of the primary internet governance bodies, developing and maintaining core protocols that underpin the internet's digital infrastructure. The IETF's consensus-based model represents one approach to open infrastructure governance that has evolved alongside the internet itself. As digital infrastructures become increasingly integrated into economic and social systems, the open standards developed by bodies like the IETF grow in importance. The processes by which these standards are created, including questions of the politics

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of participation and openness, merit careful examination.

This chapter analyses the gap between the IETF's stated principles of openness and its functional realities. These realities manifest through distinct cultural practices that often undermine the organisation's rhetorical commitment to openness. Whilst the IETF maintains a public commitment to transparency and inclusion, this research examines how decision-making unfolds in practice. By investigating the disparities between rhetoric and reality in standardisation processes, I contribute to a more nuanced understanding of technical governance models and their openness. These insights are particularly relevant as policy frameworks increasingly reference standards bodies as exemplars of multi-stakeholder governance or outsource policy making to such technical bodies (Jansen et al. 2026; Veale, Matus, and Gorwa 2023). This is often done without critically examining their actual power structures and ability to make good on their statements of openness.

This chapter builds on the book's overarching theme of understanding the politics of open infrastructures. Throughout this chapter, I demonstrate that the cultures of open infrastructure bodies, exemplified by the IETF, can entrench a political order favouring its Western male incumbent participants and dominant North American tech firms. The IETF's culture, unlike its technical products, is far from open. It can be characterised, as per the title of this chapter, as 'liberal in what it accepts, and conservative in what it does.' Consequently, these cultural factors significantly limit the democratic potential of the ostensibly open infrastructures it develops. This is because openness in protocol design cannot compensate for closure in who gets to do the designing, and infrastructures inevitably encode the politics of the corporations and communities that build them.

Analysing the cultural contours of the IETF is crucial for understanding how key digital infrastructures can or cannot—as the book's call to action—'redistribute power and drive social change.' The remainder of this chapter is structured as follows: Section 2 provides a comprehensive introduction to the IETF's structure, technical functions, and claims to openness; Section 3 outlines the theoretical framework and ethnographic methodology used in this study; Section 4 presents findings on how cultural practices undermine openness through techno-optimistic narratives and confrontational working styles; and Section 5 concludes with recommendations for open infrastructure governance.

2. The IETF: Technical Functions and Claims to Openness

'Every idiot with an email address can just show up and do work in the IETF.' This phrase was repeated across the many years of fieldwork I undertook in the IETF. By this statement, its engineer-participants mean that the organisation, and its mandate of 'making the Internet work better' (Alvestrand 2004), is accessible and open to anyone with a stable internet connection. The central aim of this chapter is to analyse whether this technical openness holds up in the messy human reality of the organisation's daily functioning.

The IETF, an industry-led body founded in 1986, is central to internet standardisation. It operates without top-down management, relying on voluntary coordination among technical actors. Whilst ostensibly open, its three yearly meetings are primarily accessible to those who can afford its steep fees and global travel. Major tech firms like Apple, Cisco, and Google dominate, with some non-commercial organisations, like the American Civil Liberties Union (ACLU)[1] and human rights organisation ARTICLE 19,[2] also participating.

To understand the precise role of the IETF requires technical familiarity with the functioning of the internet standards developed by the organisation. At their core, internet standards are agreed-upon rules that facilitate compatibility between different internet products and enable the exchange of information across its vast infrastructure. In a less technical and more widely recognisable register, this means that when individuals start the weekend by watching a film on streaming platforms, they can do so because of standards. Companies like Netflix and Home Box Office (HBO) produce the content that is available on their platforms, and this content then moves from their servers to consumer devices across a network run by telecom providers (like British Telecom, Verizon, or Turk Telecom, depending on the country). On its journey from server to device, the content is routed by companies like Cisco or Huawei. Alternatively, content can be stored and delivered via a Content Delivery Network (CDN), run by companies like Cloudflare or Akamai, where physical proximity to the user guarantees fast loading times.

1 See https://www.aclu.org/
2 See https://www.article19.org/

These different steps require a range of companies to speak to each other in the 'same language,' so that they can transport data from their servers and networks to consumer devices. This is where IETF internet infrastructure matters: without standards, these various companies would not be able to communicate effectively.

Despite this complex technical choreography, most users remain unaware of these standards while benefiting from their operation. Over the last three decades, the organisation has produced multiple key internet standards. The IETF developed the widely used Hypertext Transfer Protocol (HTTP) for data transfer on websites, the Transport Layer Secure (TLS) security protocol that encrypts such data transfer, and the Quick UDP Internet Connections (QUIC) protocol, the first new data transport protocol deployed on a wide scale in two decades. The IETF's technical contributions to internet infrastructure establish its significance in the global governance of open infrastructures.

In today's political economy, many vital internet infrastructures are developed behind closed doors by a limited set of tech industry giants. The IETF, as mentioned, relies on voluntary coordination, open working groups, and publicly accessible discussions. Its governance is characterised by the absence of top-down management, with both its meetings and mailing lists open to all who have the capacity to join online or in person.[3] Its development of open infrastructures is discussed for the world to see. The IETF is not only known for its uniquely open governance process but also for producing open standards: infrastructure that is non-proprietary, freely available for implementation and use by anyone without restrictions related to patents or royalties.

This open governance model and commitment to non-proprietary standards positions the IETF as a unique entity in internet governance, often celebrated for its democratic potential. Yet this veneer of openness is thin when examined through the daily practices through which its standards are developed. Engaging in the organisation's work on the ground, as I did for many years, reveals tensions between stated openness principles and actual participation practices.

These tensions raise a critical question: how can ethnographic

3 There are many cultural and logistical hurdles to this openness. For example, the IETF's working language is English and its meetings often happen in places with visa restrictions for people from the Majority World (Cath 2021a).

methods help us understand the IETF's distinctive culture of openness, liberal in what it accepts yet conservative in what it does, and its impact on the democratic potential of the internet?

3. Theoretical Framework and Methodology

The theoretical framework for this study draws from internet governance studies, science and technology studies (STS) and anthropological approaches to studying organisational culture in technology environments. Bringing these various fields together is necessary to bring a critical lens to the rough edges of internet governance organisations. Current academic work in the field of internet governance surprisingly barely touches on the culture of the IETF's supposedly open governance structure (Abbate 2000; Bygrave and Michaelsen 2009; Carr 2015; DeNardis 2009, 2011, 2014; Mueller 2004, 2010). Rather than adopting the prevailing characterisations of IETF as democratic, fair, and inclusive—as many leading internet governance academics do—my work departs from this existing literature by critically assessing the exclusionary effects of IETF culture. This approach also builds on STS work on infrastructure by Bowker and Star (2000) and Starosielski (2015), who have shown how internet systems often embody, and reproduce, gendered power relations.

Central to understanding the IETF's culture is Jon Postel's Robustness Principle (Postel, 1980): 'Be conservative in what you do, be liberal in what you accept from others.' Postel was an early IETF contributor and author of crucial internet standards including the Transmission Control Protocol (TCP), which played an important role in establishing the reliability and integrity of data transmission over networks. While originally intended as a technical guideline for network design, I argue that this principle has become a cultural cornerstone that shapes both technical standards and social interactions within the IETF.

One engineer I interviewed exemplified the principle's importance to governing social relations by stating, 'The corollary of the robustness principle ("Postel's law") when applied to human-to-human communication such as emails, Internet Drafts (I-Ds) and Requests for Comment (RFCs) [is]: Do not offend others, do not be easily offended.' This quote reveals how technical design principles are translated into

social norms that govern interpersonal interactions within the IETF's community.

The IETF's Robustness Principle contains distinct liberal politics that influence the organisation's governance. Following Coleman and Golub (2008), I describe the prevalence of liberal thought amongst technology communities as a cultural sensibility rather than a coherent guiding philosophy. Many legal scholars would struggle to recognise the IETF's understanding of liberalism as fitting within the traditional political doctrine that values liberty, consent of the governed, and equality before the law. Yet, the guiding logics of liberalism are clearly visible in the IETF: many in the organisation strongly valued the enhancement of individual freedom through technology.

In a 2020 paper about internet governance, Danielle Flonk et al. (2020: 366) describe this form of liberalism as rooted in the notion that the internet is an 'emerging transnational space that should mostly be governed by private self-regulation based on voluntary participation and substantive expertise.' This cultural articulation of liberalism closely matches my findings of the IETF's commitment to, and understanding of, liberalism. This liberal sensibility influences the IETF's governance, and by extension the democratic potential of its open infrastructures.

To unearth these cultural tendencies and their effects, I took an ethnographic approach. Applying ethnographic tools, including qualitative in-depth elite interviews and extensive immersive fieldwork, allows me to surface how cultural practices shape the IETF's open infrastructures. My research demonstrates that the IETF is often closed off and conservative,[4] revealing tensions between stated openness principles and actual implemented practices. My particular concern with the organisation's working practices and narratives follows from my practice-oriented approach to studying culture, which considers what people do and say, as well as the outcomes of their actions (Abu-Lughod 1991; Seaver 2017). This approach enables me to ask how things could be different, given that the IETF's culture and adjoining practices are neither natural nor inevitable.

This chapter specifically draws from multiple years of fieldwork and

4 I use the term conservative following Green (2019a: 252) to refer to the IETF's desire to maintain the status quo of its technical and social functioning, rather than referring to political affiliations.

over fifty interviews that I conducted as part of my doctoral work on the IETF between 2016 and 2021 (Cath 2021a, 2021b, 2023). Through this ethnographic lens, I examine how the IETF's culture, as manifested in its narratives and working practices, impacts who can meaningfully participate in its supposedly open governance model, and by extension the potential of participants in the IETF to drive social change. With this methodological approach established, we can now turn to the cultural barriers that limit the IETF's openness in practice.

4. Cultural Barriers to Openness

The IETF's network is not an easy one to connect to. Its culture is characterised by abrasive working practices and 'Old Boys' networks. In this section, I theorise how the exclusionary effects of the IETF's culture manifest through its dominant narratives and day-to-day working practices. I examine two key cultural elements that undermine the IETF's claims to openness: techno-optimistic narratives that mask gender inequities and confrontational working practices that privilege corporate voices above others, especially over not-for-profit public interest organisations.

These ingrained conservative practices and attitudes reinforce existing power dynamics and inequalities. The IETF's participatory processes of designing infrastructure systems through open access and open governance are not sufficient to counterbalance the closure enacted by its culture. To address the question, 'How might open infrastructures contribute to sustainable, liveable futures within the political, technological, and cultural fabrics of society?', we need to delve deeper into the cultural fabric shaped by those defining the future of the internet through open standards. This requires examining the values, assumptions, and dynamics within these communities. The next two sections will provide such an analysis, to contribute to answering the overarching questions posed in this book.

4.1 Techno-Optimism as a 'Standard' Narrative

Building upon our understanding of the IETF's structure and my theoretical framework, we can now examine the organisation's dominant

narratives that shape its cultural landscape. There is surprisingly limited ethnographic work on the IETF's narratives. The narratives that individuals tell about organisations provide an important window into their governance cultures (Forsythe 2002; Spencer-Oatey 2008). These narratives are often idealised versions of a community's history and culture (Coleman 2017) and reflect a shared set of politics. This is clearly visible in the IETF. Many of its engineers stress the internet's revolutionary promise as rooted in its open infrastructure. Their understanding of their role in society is grounded in optimistic appraisals of the network's ability to connect strangers, democratise access to information, and increase individual freedom by reducing government control over free speech, through reliance on open standards.

This technology-forward, optimistic sentiment, which sees the internet as an inherent good, also motivated its original architects (Cath 2021a; Green 2019; Nooney 2023; Paris 2020, 2026; Paris, Cath, and Myers-West 2023; Ten Oever 2023). The IETF continues to portray itself and its infrastructures as open and accessible, yet its narratives reveal a hierarchical structure enacting a closed-off culture. I will focus on one crucial narrative: the techno-optimistic view of the internet as an inherent good. How this narrative about the internet is deployed and operationalised to settle arguments within the IETF reveals dominant cultural norms that encourage engineers to be 'conservative in what they do, and liberal in what they accept.'

The deterministic legacy of this narrative remains visible in how IETF engineers talk about open standards. As if quoting from Castells (2001), Benkler (2006), and van Schewick (2011), my interviewees argue that the internet enables 'radical new forms of mass communication,' 'spurs innovation,' and 'democratises access to information' by leveraging openness. The liberatory potential of the internet, several engineers argue, is only limited by the creativity of its users. IETF documents about its work also reflect this confidence in the internet's limitless potential. Its mission statement, for example, holds that: 'The IETF community wants the Internet to succeed because we believe that the existence of the Internet, and its influence on economics, communication, and education, will help us to build a better human society.' This techno-optimism obscures the need for critical examination of who truly shapes the internet's development or reaps the benefits of its existence.

This breathless techno-optimism raises the questions: for whom and by whom should this 'better society' be built? Starting with the second question, the IETF's narrative of techno-optimism obscures the homogenous make-up of the organisation's community. An average of only ten percent of people identified as women during my fieldwork, as captured in the organisation's self-reported statistics.[5] If the IETF is inherently open, why do so few women participate? Techno-optimism provides a distinct answer to this question, which reflects the liberal tendencies of the IETF's culture. Efforts to actively recruit more women in the IETF are often dismissed with phrases like: 'We need to select for quality, not gender' or the cruder and tautological, 'If they were good, they would be here already.' The technical and procedural openness of the IETF is seen as sufficient to encourage equitable gender participation.

In the process, gender inequity is narrated as the result of women's individual choices and capacities, rather than because of the structural and well-documented barriers that women face (Abbate 2012; Brooke 2019; Hicks 2017; Nooney 2023). These dynamics relate directly to the IETF. It is evidenced in the organisation's varied responses to addressing the gender gap. Suggestions to purposefully address gender inequities in the IETF made many participants uncomfortable. They question the need for what they see as 'forced diversification,' which runs counter to their liberal politics of individual freedom. By relying on techno-optimism to explain the gender gap, my interviewees downplay the structural barriers that women encounter. In fact, some of my research participants fortify these barriers with their sexist interpretations that question women's suitability for work in standardisation.

The lack of action to improve the gender balance further impedes women from participating. As one woman told me, 'It is just uncomfortable to be in a room with literally hundreds of men and a handful of women, the drinking, the looks. It makes me feel, I do not know... out of place? Unsafe? Definitely weird.' This insight illustrates how cultural factors create real barriers to participation despite the IETF's formal commitment to openness. This quote also reflects how the larger particularities of gender dynamics in the IETF have a disproportionate impact on the ability of women to contribute.

5 See https://www.ietf.org/media/documents/IETF_Community_Survey_2021.pdf

The IETF's narratives of techno-optimism, by treating procedural openness as a guarantee of equitable access, foreclose the structural interventions that might enable women's participation. This narrative actively provides cover for inaction by individualising the problem. This reading of techno-optimism synchronises with what other ethnographers of open technology and infrastructure communities consistently found: technology's liberatory narratives mask hierarchies more than they reflect egalitarian governance (Coleman 2015; Hoffmann, Proferes, and Zimmer 2018; Marwick 2013; Nooney 2023).

The resulting organisational cultures are often conservative, in that they are likely to perpetuate and aggravate social inequities along gendered (and racial) axes, while also hampering internal and external efforts to address them. This 'dark side' of the IETF's culture was further emphasised by some of my interviewees, who were perfectly comfortable with this 'Old Boys' culture. Multiple interviewees described the IETF using this term. For example, one male IETF veteran told me, 'I think that it is still relatively an "Old Boys' Club." There are insiders, people who know how it works. And if you are not an insider and if you do not spend a tremendous amount of money getting up to speed, you are at such a disadvantage. It is so opaque.' This assessment confirms the existence of implicit knowledge and power structures that contradict the IETF's explicit claims of openness. This interviewee confirmed what others had told me in less direct ways: that the IETF's culture was easiest to navigate for its senior male participants with industry backing, and that this positional advantage is crucial to being effective in the organisation.

Beneath the IETF's optimistic rhetoric about technological liberation lies a paradoxical reality where the very narratives celebrating openness function to reinforce existing power structures. The IETF's particular form of techno-optimism surfaces a strain of liberal idealism rooted in the deeply American idea that networked technologies would inherently lead to individual freedom and liberation (Turner 2010; Nooney 2023). My analysis, in contrast, reveals how techno-optimism lets sexism in the IETF persist, as this optimistic lens hinders discussions of systemic inequality. These narratives thus restrict political interventions in the organisation's supposedly open governance model. As a result, opportunities to make the IETF more equitable and accessible are limited by its cultural standards.

There was not much appetite for changing this stark reality, at least not at the initial stages of my fieldwork. As one of the engineers I interviewed said, when I asked him about opening the IETF to women and other newcomers, 'I think the way to do this is you broaden your outreach, but you do not try to change the selection criteria. You just increase the likelihood that you will find people that will fit. As opposed to saying, we need to change as an organisation.' Such statements are reflective of a broader belief in the IETF that the organisation should explicitly resist proposed changes to its guiding narratives. Rather, many engineers argued, the IETF should focus on finding more people who would fit its existing cultural mould.

A good 'fit' in the IETF requires specific technical skills and personal traits, namely those of its incumbent majority male and Western participants. The term 'cultural fit,' as various anthropologists have explained, leads individuals to choose people that resemble them (Forsythe 2002; Marwick 2013; Nooney 2023; Traweek 1992). As a result, it is more difficult for 'misfits' to succeed in the IETF, even if they have the required technical skills; in the case of the IETF, women and participants from the Majority World. This conservative approach to engineering is 'a feature, not a bug' of the organisation's functioning, as it reflects IETF culture at large. The irreverent lack of concern for how the narrative of techno-optimism excludes capable technical individuals based on their gender, in particular, is hard to overlook.

Having established how techno-optimistic narratives create barriers, I now turn to how specific working practices further reinforce these exclusionary dynamics.

4.2 The Working Practice of 'Loud Men Talking Loudly' and their Effects

A key working practice in the IETF is confrontation. In this section, I build on the previous analysis to demonstrate the effects of confrontation for openness. First, I demonstrate how this confrontational culture further complicates women's ability to participate effectively. Second, I show how it privileges the voices of industry participants over those working for non-commercial entities, such as human rights or civil liberties organisations. Doing so, ties back to my overall argument that for open

governance organisations to reach their full democratic potential, their cultures—as much as their infrastructures—need to be conducive to that aim.

IETF working groups are characterised by frank exchanges and robust conversations. As one of my interlocutors simply said, 'Yeah, it can get a little rough.' When I asked another long-term participant to describe the nature of the IETF's functioning for me, he said, 'Oh, as tough, it is harsh. People pride themselves in their rudeness.' The working practice of confrontation is meant to standardise individual behaviour, like how the IETF standardises the internet. Being effective in the IETF requires the performance of a masculine, Euro-American approach to work that many minority participants, especially women, found uncomfortable or morally objectionable. By 'masculine' here, I specifically refer to traits culturally associated with Western professional masculinity: assertiveness bordering on aggression, a preference for direct confrontation, and emotional detachment during technical debates.

This rude and boisterous working practice often arose in my interviews when I asked how the IETF worked. It was evidently visible across my many years of fieldwork and reflected in the organisation's 'archival hubris' (Kelty 2008: 114). The IETF's original guidance document for newcomers, for example, warned that participants 'can sometimes be surprisingly direct, sometimes verging on rude.'[6] I attended multiple newcomers' sessions during my fieldwork and was surprised by the levity with which newcomers were ushered into the IETF's hostile working culture. Veteran IETF participants shared advice such as, 'Do not take it personally' and 'People are just very passionate' to deflect critical questions about the roughness of the IETF's working practices. One of my interviewees was relatively new to the IETF at the time of our conversation. She explained why this practice of confrontation was off-putting to her:

> The thing they say in the newcomers' training, which is right up with the weird focus on wearing t-shirts, is that 'passionate men like to argue loudly.' And like to me, that is messed up. Right? We should not be inoculated to that kind of behaviour, that is really clearly a symptom of a larger cultural problem and actually not something that you should be

6 For the full document at that time, see: https://web.archive.org/web/20210318203553/https://www.ietf.org/about/participate/tao/

> proud of. It also desensitises people already here, and new people, to abusive behaviour, basically.

This critique highlights how behaviours that are normalised within the IETF culture can appear problematic or even abusive to newcomers, particularly those from different cultural backgrounds or communication styles. Such practices impact who can comfortably participate in technical discussions. Multiple ethnographers of open technology communities have demonstrated that this rough approach to work creates organisational cultures that are especially unappealing and hostile to women, people of colour, and individuals with explicit political agendas (Dunbar-Hester 2019; Ensmenger 2015; Reagle 2013).

The exclusionary nature of the IETF's confrontational working practices is especially visible in the IETF's unofficial tradition of 'loud men talking loudly' (Cath 2020; Cath 2023). Many IETF participants, however, insist that these acrimonious and noisy practices are crucial to developing good protocols because confrontation is seen as key to both the IETF's social functioning and the internet's technical functioning. Leach, Nafus, and Krieger (2009: 5) describe the salience of confrontation in the context of open-source communities as a reciprocal dynamic because 'better software is seen as dependent on particular social practices and ideologies while these practices and ideologies are given salience by their success in fostering valuable production.' This connection between confrontation and production is in equal measure visible in the IETF.

This confrontational style is clearly reflected in other aspects of the IETF's daily functioning. Its impact is visible in how several long-term women participants had adapted their style to match that of their male counterparts. One woman newcomer remarked to me:

> There is a lot of misogyny here. Which is not expressed, this culture makes it very hard to talk about that. We are talking about entities, we are talking about machines, and autonomous systems and so on, so the social things are 'not a problem.' The women, the older women, are like men. They learned how to move their bodies like men, and they speak louder, it is interesting.

This observation captures a theme: to succeed in the IETF environment, women must perform masculinity, effectively erasing gender difference

to gain technical credibility. This quote also demonstrates that women are expected to take on these confrontational and loud masculine practices. Vice versa, I witnessed how women who took a less loud approach struggled to get their voices heard. These realities demonstrate how the IETF working practices are prejudiced against the participation of women. There are no formal documents that contain these implicit rules about the importance of a masculine attitude; women find out by existing within the space. On occasion, this also happens in blatantly sexist ways. I saw male engineers judge women for wearing makeup, or formal wear. I heard them question their ability to fulfil IETF leadership positions while having children, or when pregnant. The IETF's working practices are enforced through this collective culture that categorises non-masculine work styles, and life trajectories, as deviant.

The unwritten nature of these cultural rules makes it hard to alleviate its most concerning outcomes, including overtly sexist and racist behaviour. The IETF's culture encourages its members to adhere to the standard set by its incumbents, and their masculine and Western approach to engineering. This approach to work, as also identified by other scholars who studied the tech industry (Hicks 2017; Nooney 2023; Paris 2020), normalises gendered power imbalances while purporting to champion accessibility and openness.

In practice, rather than engendering openness, much like the techno-optimistic narrative, this culture hinders discussions of systemic inequality. Individuals who could not or would not perform this working style often left the IETF. Yet, their departure is not necessarily seen as a problem. Confrontation and a focus on technical work, in the eyes of many of the IETF engineers I spoke to, led to 'getting work done.' One senior IETF engineer said, 'If we become too sensitive, we cannot have the arguments we have to have. [...] if people are holding things back then you end up with of all of this subterfuge.' This quote reflects the cultural currency of confrontation, as well as the conservative nature of IETF culture, which did not change in the face of these exclusionary undertones and only cemented a broader trend of abrasive masculinity and gender discrimination visible across the tech sector.

Considering this exclusionary pattern, I pressed my interviewees about the continued role of confrontation given its discriminatory

effects. One senior engineer summarised what multiple people told me. He said, 'We do not have the resources to engage with the entire planet on the evolution of the internet and talk people through why each individual idea is a bad idea. And so, making people put some effort into coming to us, is important.' This statement reveals a broader insight about the IETF: confrontation serves not only as a cultural preference but as a deliberate filtering mechanism that limits participation. Confrontation is thus not only about developing good protocols but also designed to deter non-incumbents from participating in the IETF, or at least from doing so with relative ease. Given the historically skewed participant base of the IETF, this deterrence mechanism disproportionately impacts women. But as I will argue in the next paragraphs, it also privileges the voices of commercial actors over non-commercial voices.

The development of open infrastructures at the IETF is heavily influenced by economic dynamics. IETF engineers hold that their contributions are 'on their individual titles,' which means that even though it is often their (corporate) employers who pay for their participation, engineers do not explicitly identify as representing their employers' perspective. However, during my fieldwork, I found that corporate affiliation mattered a great deal. The opinions of engineers working for companies that develop leading operating systems (like Apple and Google), account for a large percentage of internet traffic (like Google), or are dominant in the browser market (like Google) often decide heated technical arguments.

The importance of company affiliation puts those working for non-commercial institutions, including public interest organisations, like human rights or civil liberties organisations, at a structural disadvantage. Even though these public interest organisations believe they represent a wide set of internet users, given each person has human rights or civil liberties, their organisations are not recognised as influential in economic terms. Their lack of commercial clout makes it even more important for these actors to engage in IETF to ensure the concerns they bring are heard.

One engineer I interviewed recalled a meeting where he was sitting on a podium facing the IETF community during its plenary meeting. Staring at the 1000-odd people in the room, he realised:

> If you sit upfront and look out at the crowd, what you see is a tremendous lack of representation: it is mostly old white guys. A lot of the IETF members are "greybeards," and a lot of them are perfectly happy with the way things are because it works for them because the IETF is totally tuned for greybeards. But it is not tuned for women. It is not tuned for people living in Africa, for people in Australia. It is not tuned for people who have trouble following English.

This visual observation encapsulates the skewed demographic reality that belies the IETF's claims to global openness and accessibility. Furthermore, it captures my overall findings about IETF culture: it is optimised for a narrow set of white male participants working for industries from North America and Europe. The IETF's working practices are narrowly aligned with Western cultural practices that value a detached and technical, but at the same time playful and irreverent, individualistic work ethic. The organisation's working practices hamper the participation of more diverse demographics. The IETF's reliance on masculinity and corporate affiliation presented additional hurdles for minority participants, especially women. The importance of corporate clout, furthermore, limits the inclusion of voices and concerns from communities without a commercial stake in the future of open standards and infrastructures.

5. Conclusions

This analysis of the Internet Engineering Task Force's cultural contours demonstrates that open digital infrastructures cannot effectively redistribute power or drive social change, when their governance bodies remain culturally closed. The IETF's approach to open standards mirrors its Robustness Principle: liberal in acceptance, conservative in action. This culture reveals the hidden human factors and motivations driving infrastructural decisions. Engineers make decisions that reflect tech industry power dynamics, whilst rough working practices deter women and public interest advocates who might provide counter-power in debates about open infrastructures.

The IETF's conservative stance resists cultural shifts that could modernise its governance and open space to bring a sorely public interest perspective to the individuals developing the current and future internet.

My findings emphasise the need for further ethnographic engagement with these internal dynamics of open (internet) infrastructure governance institutions. The IETF's actual practices often contradict its lauded reputation, raising doubts about the broader suitability of such standards bodies as a model for open tech communities. Academics studying internet governance should not hesitate to name such narratives for their inequitable effects, even if they are part of the cultural canon of open infrastructure organisations, or internet governance writ large.

The cultural dynamics I observed in the IETF have broader implications for the tech industry and other open infrastructure organisations. The techno-optimistic outlook, confrontational working style, and tension between technical openness and cultural closedness reflect wider trends in the technology sector. These cultural factors contribute to the lack of diversity visible in many other tech and open-source communities. I demonstrated why such standards bodies and open-source projects may benefit from examining their own cultural practices considering these findings.

My findings are crucial for informing policy debates on tech regulation and stakeholder engagement, particularly given the EU's trend of outsourcing legislation to standards bodies. Policy makers should exercise caution when delegating policy objectives to standards bodies dominated by 'loud men' and 'old boys.' This research exposes the limitations of using such bodies as policy vehicles, given their often-inherent conservative cultural biases. The IETF's reliance on exclusionary cultural practices is especially concerning due to the lack of external oversight and the importance of equitable participation in digital infrastructures.

There are, however, promising developments for the future. The IETF is implementing new, progressive measures such as an Ombudsteam, which allows individuals to confidentially report and raise concerns about harassment and other conduct in the IETF, and free childcare to improve gender inequity. Whilst the long-term impact of these efforts remains uncertain especially in the current political climate, the way forward is clear—including to those within the organisation: the IETF must directly confront the cultural norms that perpetuate systemic biases and exclusionary practices. Progress requires moving beyond basic principles of mutual tolerance towards actively tackling

systemic biases and creating more space for non-commercial voices in setting the standard for open infrastructures. Ultimately, understanding these cultural issues is crucial for ensuring that tech governance, and open standards-setting processes, serve the public interest rather than narrow corporate agendas. Open infrastructures, it turns out, are only as liberatory as the cultures that produce them.

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2. From Free Software to Open Source: Traversing the Terminologies, Values and Ethics of an Open Knowledge Infrastructure

Renée Ridgway

> If, as Langdon Winner famously states, the politics of technology are about 'ways of building order in our world,' then hacker and geek politics are geared toward reordering the technologies and infrastructures that have become part of the fabric of everyday life (Coleman 2011: 515).

1. Introduction

The coinage Free Software goes back to the 1980s where it was once valued for its 'peculiar form of potentiality,' not per se a thing or technology or license, but something that had possibility (Kelty 2013).[1] At that time, the ethics of Free Software, which is 'open' and not proprietary, were immanent to nascent computer science departments worldwide and people came to Free Software as the solution, enacting 'disruption in the creation, circulation, distribution and control of knowledge' (Kelty 2013). Simultaneously Free Software embodied

1 A discussion of FLOSS and open-source licenses, though fascinating, are beyond the ken of this article.

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a politics of liberalism, with its roots anchored in UNIX, situated within the hybrid academic-corporate culture of Bell Labs, which were critical of software development by corporations, organisations or consultancies (Kelty 2008). Eventually, this politics took form in the acronym FLOSS (Free/Libre and Open-Source Software), articulated by Richard Stallman, who opposed proprietary software 'hoarding' (Kelty 2008: 99). Here, the 'L' signified 'libre,' meaning 'free,' not as in 'free beer' but 'free speech,' standing for the 'free flows of information' and taking no position on economic flows (Schneider 2021: 47). Stallman's conception of Free Software was a pushback against the 'piracy problem' that Microsoft's Bill Gates had already raised with his infamous 'Open Letter to Hobbyists' (1976) that complained about the sharing of software through hobbyist magazines.

In 1991, a Finnish computer science student (Linus Thorvalds) developed and maintained a 'small kernel that could run alongside free software tools' for his personal computer at home that came to be known as Linux (Driskoll 2015: 274). This operating system eventually served as the 'first material bridge between institutional computing infrastructures' such as those at MIT (where Stallman was located) and previously, the personal computing world of IBM (Driskoll 2015: 274). However, during the dot-com boom, the usage of the term Free Software became a governing force in online start-ups (Amazon, Yahoo!), which incorporated pragmatic approaches by saving costs, promoted by the 'evangelism of the libertarian pro-business hacker Eric Raymond' (Kelty 2008: 99). At the Linux Kongress in 1997, Raymond delivered his lecture 'The Cathedral and The Bazaar' that described the experimentation with Free Software (the 'bazaar'), and its applications, methods, and adoption by industry (the 'cathedral'). Also in 1997, Tim O'Reilly, who published handbooks for Free Software, organised the Freeware Summit conference, with Stallman not invited. It was here that Raymond first suggested using the term 'open source,' which enhanced a shift from Stallman's 'L' for liberty or free (as in information and speech) 'in order to better appeal to corporate partners' (Morozov 2014 cited by Schneider 2021: 7). In 1997, Bruce Perens published the first manifesto of open source, the Debian Free Software Guidelines (DFSG) and together with Raymond, co-founded the Open Source Initiative in

1998. Derived from the DFSG, once 'The open source definition' was published, Stallman decided there was a need to differentiate this from his own 'Four Freedoms' for Free Software.[2] Simultaneously, Raymond focused on the rise of the internet economy and making Free Software 'into something that made more sense to investors, venture capitalists, and the stock-buying public' (Kelty 2008: 109).

At the same time, the Free Software movement became affected by economic factors, namely the bursting of the dot-com bubble, and it morphed into many things: 'a problem, a danger, a job, a calling, a dogma, a solution, a philosophy, a liberation, a methodology, a business plan, a success, and an alternative' (Kelty 2008: 115). Based on his ethnography consisting of participant observation, interviews with self-proclaimed 'geeks,' archival documents, and an analytical history of the preceding years, Chris Kelty's 2008 book, *Two Bits—The Cultural Significance of Free Software* shows how the 'movement' constantly argued about and discussed Free Software. This encompassed the practices of talking about the meaning and necessity of four other practices: sharing source code, conceptualising openness, applying licenses, and the practice of coordination and collaboration (2008: 98). Based on the differences mentioned above, 'the movement' became polarised and heated and Free Software 'forked' into open source 'a term previously used only by the CIA to refer to unclassified sources of intelligence' (Kelty 2008: 99).[3] One of Kelty's contribution was to elucidate that by 1998–1999, on the one hand 'Free Software' was about rights and liberty whilst open source was concerned with 'political agnosticism or nonideological commitments to "fun,"' yet the practice is identical, which is an advantage as 'they are all nonetheless contributing to the same mysterious thing' (Kelty 2008: 112).

2 The freedom to run the program as you wish, for any purpose (freedom 0). The freedom to study how the program works, and change it so it does your computing as you wish (freedom 1). The freedom to redistribute copies so you can help others (freedom 2). The freedom to distribute copies of your modified versions to others (freedom 3). See https://www.gnu.org/philosophy/free-sw.en.html

3 Throughout this chapter I have attempted to keep the authors' and informants' original acronyms (FOSS, F/OSS, FLOSS) to describe Free Software and open source as opposed to proprietary software, which is usually abbreviated as OSS and has more innovation and/or business connotations, yet terminology usage is not always consistent.

Twenty-five years later, this chapter enquires whether these practices and politics still ring true, along with how and when F(L) OSS and open source could be considered 'open (knowledge) infrastructures' and what types of ethics or values are (still) embedded within them. It unfolds by first examining the historical transformations and semantic shifts within the FLOSS movement, highlighting the political, socio-technical, and knowledge conditions under which these shifts occurred, thereby providing a perspective for understanding current political configurations of FLOSS initiatives. It then asks what constitutes an open knowledge infrastructure, drawing on classical science and technological studies (STS) infrastructure texts. To grasp this interplay between technical infrastructures as artefacts and human organisation, as well as the ethics and politics embedded within (Winner 1980; Star 1999: 379), speaking directly with those embedded in these practices is essential. The study consists of semi-structured interviews or 'epistemic encounters' (Kelty 2008) with developers, academics, 'geeks,' and awardees from NGI (Next Generation Internet) Search projects, which have to be made open source upon completion.[4] A critical discourse analysis interweaves excerpts on empirical data gathered on ethics and values from semi-structured interviews structured by Star and Ruhleder's 'dimensions' (1996) or Star's 'properties' (1999) of an 'emerging infrastructure.' By elucidating the techno-infrastructure through the medium itself (code), the findings go beyond the critique of open source as a solution to proprietary software and of copyleft[5] ideology, showing how these approaches differ on an ethical, rather than technical, level. In this way, the Free Software 'movement' of past decades resurfaces through the makers/practitioners of today, who, according to the author, could be considered a 'recursive public' (Kelty 2008). The chapter contributes to critical infrastructure studies and STS literature by demonstrating that F(L)OSS is an open (knowledge) infrastructure when it is open, political, and collectivised, not only through open-source code but

4 See https://www.ngisearch.eu/

5 Copyleft is a legal licensing technique that allows certain freedoms (modify, share, copy, and redistribute) for copyrighted works as long as the derivative works preserve the same rights.

through the people who enable the infrastructure to exist, enacting maintenance and care as a commons of potential.

2. The Politics (or Lack Thereof?) of FOSS Initiatives

As explained above, the social and technological practices of F/OSS exhibit certain elements of the liberal tradition, where the emphasis came to be placed on 'knowledge, self-cultivation and self-expression as their ethical philosophy' (Coleman 2013: 3). However, it was through cultural positioning and the 'rearticulation of free speech principles' that orchestrated the dynamics of what Gabrielle Coleman describes as the 'political agnosticism' of FOSS (2004: 509). This denial of formal politics or lack of political intention ignited a way to reconsider intellectual property rights by directing it 'toward the protection of free speech, instead of its "conventional use" of securing property rights' (Coleman 2004: 508). For many Free Software enthusiasts, code is considered speech and the 'L' (libre) signifies the right to access and create free information flows. Therefore 'free speech' was seen as 'free code,' and as McInerney notes, the 'source code,' which is the recipe for software, invites users to modify it (2009: 209). Composed of people, 'skilled programmers, security researchers, hardware builders and system-administrators,' FOSS opened up a window on to the liberal values of free speech, though a 'cultural-based technical practice: that of computer hacking' (Coleman 2004: 508).

In this way, FOSS was informed by computer techniques that constitute hacker values. Free Software programmers took pleasure in building and configuring whilst communicating and collaborating as 'forms of value by inhabiting technology' (Coleman 2011: 512). Other values that came into being through Free Software included 'competitive mutual aid, avid free speech principles, and implementation of meritocracy' all while challenging the intellectual property establishment (Coleman 2013: 3). The power of Free Software was to make these values, or principles, into material objects and thereby able to be 'manipulated, reconfigured, tested and torqued'—radically open to change and promoting process over product as an infrastructural and material strategy for a new world (Kelty 2013). Creating alternative software licensing and establishing

hacker values motivated their 'commitments to freedom of information, geeky production, culture, and action,' along with instantiating new ways for 'collaborating, organizing, and protesting' (Coleman 2011: 513, 515).

As shown by Ben Birkinbine's research (2020), the revolutionary changes ignited by FLOSS and other commons-based peer production were co-opted by these corporate structures and strategies. Although Free Software was an amazing human achievement, with Liberty removed from the equation, in Raymond's ideal (open source), the innovative nature of software production was through the 'development model' that would lead to mass revenues through the stock market (Kelty 2008: 109). In his 2015 article, Birkinbine focuses on the acquisition of Sun Microsystems by Oracle and shows how corporations became increasingly involved in FLOSS projects (and nowadays even more with the development of GenAI), yet these clashed with the community 'ethos' of FLOSS. Coleman articulates the ethos as a 'belief in productive freedom' that includes the right to 'autonomously improve upon their peer's work, refine their technical skills, and extend craftlike engineering traditions' (2013: 3), without a corporate infrastructure dictating the terms and licenses. Giacomo Poderi's ethnographical study of a FOSS videogame community reflects this positioning by articulating the 'relationship between continuous design and software development distributed infrastructure' (2014: 78). Echoing Coleman's 'belief in productive freedom,' Poderi emphasises the 'user-driven and self-organizing construction processes' of the FOSS commons through 'collective and bottom-up management,' drawing on Star (1999) and Star and Ruhleder's (1996) ecological approach to infrastructure (2014: 80).

3. When Is an Infrastructure a Complex and Relational Ecology?

In her seminal text, 'The Ethnography of Infrastructure,' Susan Leigh Star proposed the ecological as a 'methodological perversion,' putting forth those people and things which had been neglected with the studying of 'boring' things, such as infrastructure (1999: 379).

Star insightfully argued that infrastructures are not only ecological, but also relational and material constructs made by humans (1999: 382).

Star draws on Gregory Bateson, who claimed that 'What can be studied is always a relationship or an infinite regress of relationships. Never a "thing"' (1978: 249), to show how infrastructures are impacted by other things. With technical systems that serve as larger infrastructures, it is often not the infrastructure as a whole that becomes visible, but the specific component that matters to a given user: the rail to the engineer; the stairs that become barriers for wheelchair users; the water system that is essential to a cook; or, for a plumber, the very same water system, understood as a 'target for repair' (Star 1999: 380). Often seen as the invisible infrastructure hovering in the background supporting other forms of work, Star uses the example of computers to comically state that if we were to conceive of them 'more modestly as symbolic sewers' instead of information highways, 'this realm would open up a bit' (1999: 379). Because for Star, if an information system is investigated without also exploring its 'standards, wires, and settings,' the researcher can overlook the 'equally essential aspects of aesthetics, justice, and change' (1999: 379).

During the mid-1990s, with the rise of decentralised communication technologies that encompassed large swaths of land, there was a growing need for shared standards as well as 'situated, tailorable and flexible technologies' (Star and Ruhleder 1996: 112). In their 1996 article 'Steps Toward an Ecology of Infrastructure,' Star, along with Karen Ruhleder, describe the building of the Worm Community System (WCS), a 'geographically dispersed, sophisticated digital communication and publishing system [software] for a community of scientists.'[6] Worm software was designed and constructed for biologists with an intention to 'create infrastructural tools for research' and to 'transform local laboratory organization,' whilst simultaneously competing with the expansion of finding information on the internet with search browsers (Gopher and Mosaic) (Star and Ruhleder 1996: 112). Additionally, Star and Ruhleder built upon the scholarship of Yrjö Engeström, who asked 'When is a tool?' to demonstrate that a thing becomes a tool in practice and when it is connected to an activity (1990). During their study, Star and Ruhleder subsequently enquired 'When, then, is an infrastructure?' (1996: 113).

6 For a detailed description of its vision, please see: http://wbg.wormbook.org/wli/wbg11.4p6/

In order to map out the 'emergence of infrastructure,' Star and Ruhleder came up with a list of 'dimensions,' which are without an 'absolute boundary on an a priori definition' (1996: 112–113)—what Star later called 'properties' (1999). Star and Ruhleder's findings showed that not many biologists ended up using Worm, but also that infrastructure does not just reside in the background but 'emerges for people in practice, connected to activities and structures'—it is a relational concept. In her 1999 article, Star reflects back on this research, where she imparts that even though they (Star and Ruhleder 1996) were following certain principles of participatory design, they began to 'see infrastructure as part of human organisation, and as a problematic as any other' (1999: 380). In the following sections, I apply these dimensions or properties to structure interviews (epistemological encounters) with a range of software developers, geeks, and hackers to find out if and when F(L)OSS emerges as an 'open infrastructure.'

4. Epistemological Encounters

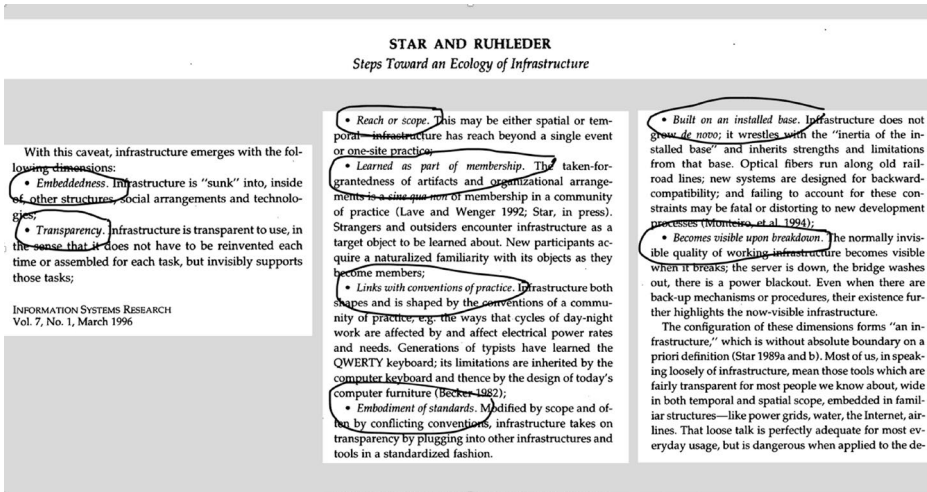
Infrastructures are not only complex and relational ecologies. The system's development process is also about gathering communities together who have very diverse approaches, for example regarding the values and ethics of building computing infrastructure and software. This chapter therefore draws on fourteen semi-structured interviews conducted both face-to-face and virtually from December 2023 to September 2024, each lasting approximately 1.5 hours. It also consists of historical analysis, tracing categories of infrastructures, delving into the development of technologies and reading literature (archival texts, articles, and books). During this period, these interviews were augmented by participant observations—informal and ad hoc conversations at various F(L)OSS conferences through introductions by previous 'informants' that adhere to the 'snowball' method. As with Judy Wajcman's study on calendars in Silicon Valley, the research is located within the 'broad ecology and cultural life' (2018: 1280), in this case people living in F(L)OSS and open-source development communities. Also taken into consideration is that people 'make

meanings based on their circumstances' and world experiences that are also 'inscribed into their judgments' concerning technology and the 'built information environment' (Star 1999: 383).

This type of fieldwork could be considered a 'distinctive mode of epistemological encounter' that offers a means to reflect on the process during and after the 'material labor of fieldwork,' which occurred whilst engaging with the 'material labor of writing and rewriting' (Kelty 2008: 18, 20–21). In the beginning, the research was about the values and ethics of Free Software as 'a kind of complex technical practice' (Kelty 2008: 21). Echoing Kelty, who 'could not have identified "recursive publics" as the object of the ethnography at the outset' (2008: 18, 20–21), during the coding of the data and writing this chapter, quite unexpectedly it came to mind whether theses informants could also be considered a 'recursive public,' which this chapter will return to below. Therefore, as with much research writing, the reflection and writing process enables one to 'reorient it into a question that will have looked deliberate and answerable in hindsight' (Kelty 2008: 20–21).

Furthermore, when choosing informants the aim was to be inclusive of professions (designer, software engineer, academic, non-profit director), gender (non-binary, women, men), continents (South American, North American, European), ethnicities (Brazilian, Indian, Finnish, Belgian, American, German, British, French) and financial interests (grant awardee, freelancer, self-employed, employee). The informants are anonymised, as agreed upon before the interview took place, and assigned a number. After conducting the epistemic encounters with the informants, the data was then 'coded,' based on what Star and Ruhleder (1996) define as the 'steps toward an ecology of infrastructure' by way of the specific dimensions/properties with small additions or adaptions (1999). Although they were not defined as values as such, (re)reading these dimensions or properties brought to mind many of the ethical considerations that the informants mentioned and that structure the content of the interviews.

5. Emerging (Open) Infrastructures



STAR AND RUHLEDER
Steps Toward an Ecology of Infrastructure

With this caveat, infrastructure emerges with the following dimensions:

• *Embeddedness*. Infrastructure is "sunk" into, inside of, other structures, social arrangements and technologies;

• *Transparency*. Infrastructure is transparent to use, in the sense that it does not have to be reinvented each time or assembled for each task, but invisibly supports those tasks;

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• *Reach or scope*. This may be either spatial or temporal—infrastructure has reach beyond a single event or one-site practice;

• *Learned as part of membership*. The taken-for-grantedness of artifacts and organizational arrangements is a *sine qua non* of membership in a community of practice (Lave and Wenger 1992; Star, in press). Strangers and outsiders encounter infrastructure as a target object to be learned about. New participants acquire a naturalized familiarity with its objects as they become members;

• *Links with conventions of practice*. Infrastructure both shapes and is shaped by the conventions of a community of practice, e.g. the ways that cycles of day-night work are affected by and affect electrical power rates and needs. Generations of typists have learned the QWERTY keyboard; its limitations are inherited by the computer keyboard and thence by the design of today's computer furniture (Becker 1982);

• *Embodiment of standards*. Modified by scope and often by conflicting conventions, infrastructure takes on transparency by plugging into other infrastructures and tools in a standardized fashion.

• *Built on an installed base*. Infrastructure does not grow *de novo*; it wrestles with the "inertia of the installed base" and inherits strengths and limitations from that base. Optical fibers run along old railroad lines; new systems are designed for backward-compatibility; and failing to account for these constraints may be fatal or distorting to new development processes (Monteiro, et al. 1994);

• *Becomes visible upon breakdown*. The normally invisible quality of working infrastructure becomes visible when it breaks; the server is down, the bridge washes out, there is a power blackout. Even when there are back-up mechanisms or procedures, their existence further highlights the now-visible infrastructure.

The configuration of these dimensions forms "an infrastructure," which is without absolute boundary on a priori definition (Star 1989a and b). Most of us, in speaking loosely of infrastructure, mean those tools which are fairly transparent for most people we know about, wide in both temporal and spatial scope, embedded in familiar structures—like power grids, water, the Internet, airlines. That loose talk is perfectly adequate for most everyday usage, but is dangerous when applied to the de-

Fig. 2.1 Star and Ruhleder's *Steps Towards an Ecology of Infrastructure* (1996), annotated by the author of this chapter.

5.1 Embeddedness, Installed Bases, Scope, Transparency, and Community

As shown in the preceding sections, Kelty's contribution demonstrated that even though two ideologies existed, the movement was mostly arguing about 'doing the same thing' (2008), which is supported by one informant's (12) declaration: 'There is no difference between open source and F(L)OSS from a user perspective.' This reaction highlights the property of embeddedness: as with many infrastructures, people do not necessarily perceive distinctions because these systems are 'sunk into and inside of other structures, social arrangements and technologies' (Star and Ruhleder 1996: 112–113; Star 1999: 381). Another informant (4) insisted on using the terms F(L)OSS and open source interchangeably, whilst two informants (1, 2) highlighted F(L)OSS as being 'an infrastructure for interoperability of software projects.' For Star and Ruhleder's study (1996), it was users' entrenchment in Macintosh systems that affected their study, whereas during the interviews many informants mentioned a different 'crucial infrastructure'—the Linux operating system, which is a community-based project licensed under the

GPL and widely used as a mainstay for enterprise-scale infrastructures all over the world with open-source code. This embodies what Star and Ruhleder (1996: 381) and Star (1999: 381) point out, namely that '[i]nfrastructure does not grow *de novo;* it wrestles [...] and inherits strengths and limitations' because it is built on the inertia of an installed base. It also reflects the dimension of reach or scope, which describes how infrastructures go beyond 'one-time usage or one-site practice,' and can be expressed either spatially or temporarily (Star 1999: 381).

Reach or scope also ties into the politics of open infrastructures, particularly questions of governance and transparency, which is enacted by the degrees of openness that are 'implicit in both terms' and as one informant (1) emphasised, they wanted 'to be able to look at code.' However, another (7) was hesitant to apply the term openness to either F(L)OSS or open source, noting the rise of 'open-washing':

> this terminology is tricky, because there is now openwashing, where calling everything open is a trend as with the company OpenAI, which uses misleading language [in its name].

This type of co-optation applies not only to the term 'open' but to proprietary software, which, as another informant (3) explained, 'gives power to companies to control the power structures' and 'that's were F(L)OSS comes in—it captures autonomy and transparency to make power structures on the side of people.' Depending on the business model, both F(L)OSS and open source can be strategically non-transparent and disruptive, by withholding the code, as explained by one informant (12) who emphasised that sometimes you can't instantly be open about everything: 'As a shareholder, you get it when it's made open, but not every step of the way.' However, they continued by adding that both F(L)OSS and open-source software (OSS) require people (i.e. programmers) to be:

> open, free and transparent. Even if you don't like them, if their code is valid, then there needs to be a way to work with people in an open way.

Another informant agreed, stating that code should be made open source at certain points in time and, above all else, code must be written in a language that still exists, and that it 'needs to be beautiful.' They added that it has to be tested in a 'lively community,' because all of these properties are necessary in order for code to be able to 'receive a future.'

This brings us to another important dimension of an ecology of an infrastructure: community. With both F(L)OSS and open source, outsiders have to become familiar with the code so that it becomes 'learned as part of membership,' which helps familiarise newcomers with the 'taken-for-grantedness of artefacts and organizational arrangements [that] is a *sine qua non* of membership in a community of practice' (Star 1999: 381). Another informant (2) articulated this as understanding the importance of membership, which involves 'running F(L)OSS communities and reining in awareness,' whereas for another (3) it is 'about passion, people, community and the way we can build a digital society. People together with F(L)OSS is a way to get there.' One informant (8) summed it up by evoking the holy trinity (use, contribute, and maintain)—common lingo in F(L)OSS and open source circles—explaining that within communities, the 'antithesis is the lurker. The idea is to convert the lurker into a contributor.'

5.2 Conventions of Practice and Embodiment of Standards

'Infrastructure both shapes and is shaped by the conventions of community practice' (Star and Ruhleder 1996: 112–113; Star 1999: 381), which was vocalised by many informants who expressed this in varying ways. Seemingly, the argument was that everyone has to respect the four freedoms or 'the open source definition,' and that these conventions of practice operate similarly across F(L)OSS and open source, once again confirming Kelty's observations (2005; 2008; 2013). Another informant (4) also views FOSS and open source as the same thing, which operate as 'embodied ethics' because they are:

> an ethos and a gift economy. I wanted to give and protect my gift. I wanted no one to claim ownership of something. Giving and sharing empowers people [...] and there is actually a lot of power in giving something for free [...] it attracts people.

However, differences surfaced and these were pointed out when it came to their politics. One informant (1) declared that open source or F(L)OSS on a technical level is still the same yet on an ethical level it becomes a 'totally different discussion.' Or another one (2) formulated their thoughts this way: 'It is about ethics. Is it giving up authorship? No, it [F(L)OSS] is altruism.' Others stated that 'F(L)OSS is a commons' (1, 2, 5, 6, 10, 11) or 'a public good' (6) and that F(L)OSS 'needs to be

protected from corporate encroachment' (10).

Returning to the historical debates, one informant (1) recounted the competition between the two as an '(uneven) boxing match,' where at one conference they attended everyone who wanted to make big money was in the open source corner, while those who wanted to build for the community were in the other corner. For them, the delineation is still apparent. For another (9) the 'line has been reinforced' recently when they stated that:

> I've done a fair amount of contributions [...] working for free for Google, Facebook [...] they feed us horrible politics. Now there is a real line to draw somewhere.

These statements refer to how Big Tech builds on open source code and then makes its products and services proprietary. Another informant portrayed open source as being about 'taking care of business and locking you in to the product' (2) or describing how big business is built on Free Software:

> The open source way is like reinventing the wheel. The core is 'open source,' but stock management invoicing is proprietary. So it is open but there is still a business model attached to it. (12)

An additional link to conventions of practice that shapes open infrastructures is the notion of 'pragmatic philosophy,' also in regard to governance. One informant (11) specified that as an infrastructure, open source is about 'pragmatic methodology' and that Free Software is like a 'philosophy or a political ideology.' Another (7) declared that 'OSS became the pragmatic business term because they [coders] wanted to step away from politics [FLOSS].' Or for another (10) it came down to framing difference through intellectual property rights. OSS was a protection for a shared ownership of 'the thing' and you maintained it because you were part of that ownership:

> Non-permissive licences are the favourite word of businesses [...] However, software that is not open source is doomed from the get go. If things are made public there stands a chance, but if it is considered IP (Intellectual Property), then no way.

One informant (8) expressed the hijacking and coveting of code by open source as the 'power of privilege,' whilst another (12) framed the discussion explicitly through values: 'Open source sometimes claims

"responsibility," which means they think they can make money without doing anything.' This was also echoed by another informant (9) when describing Silicon Valley behemoths:

> Amazon web services is a multibillion company built on open source, yet has a permissive licence. They take it [code] and made it proprietary and therefore they are a bad company. It is extractive capitalism [...] If you want it back it will cost you 10 Euros a month.

Infrastructures might also be modified by conflicting conventions, as with another informant (8) who depicted the shift in terminology from F(L)OSS to open source as a 'winding road of forked paths. Open source meets its own incongruency as things made messy by humans who build it together.' This literal metaphor of a road reflects what Star and Ruhleder elucidated as an embodiment of standards, whereby infrastructures 'take on' transparency by plugging into other infrastructures and built on an installed base, in standardised ways that are themselves 'modified by scope' (1996: 381). Or, continuing this metaphor further, one informant (2) declared that FOSS is 'fundamental, as you cannot create roads that go across countries without it.'

5.3 Visibility through Breakdown

Additionally, the word sustainability often arose in the encounters, with one informant (7) pointing out the fact that 'sustainability and viability is now a big conversation' in the open-source community, whilst another (4) referenced Bruno Latour's 'technology is society made durable' (1990) in regard to open-source software.[7] Already in 1996, Star and Ruhleder put forth that our working infrastructures become visible upon their breakdown, citing data servers or roads being washed out or power blackouts as examples, with Star later emphasising that the breakdown 'became the basis for a much more detailed understanding of the relational nature of infrastructure' (1999: 382). Thirty years later, breakdowns (and blackouts) still occur in infrastructures, yet it seems that 'it is not sustainability but maintain-ability,' because, according to

7 Bruno Latour argues that technology is not separate or distinct from society but is an extension of it as it embodies social relations, power structures, and cultural expectations.

one informant (10), 'sustainability is not guaranteeing sustainability. We need to have a future.'[8] Another (2) backed this up by declaring that 'everyone wants to invent the wheel, but they don't want to maintain it.' Recognising the necessity of their role, because 'along with developers, maintainers are really important,' another (4) used the exclamatory 'the pain of maintenance!!!!' to express their commitment and exhaustion. Moreover, the maintain-ability of code also surfaced through a contemplative, historical, and philosophical reflection: 'There are always bugs... I call them the "longue durée" of living with software' (10).[9] Returning to Star and Ruhleder's nomenclature, one informant (11) used the term 'ecological,' in regard to how F(L)OSS or open source as an infrastructure needs to exist with 'long-term functionality' so that it can be sustained by others. This was echoed by another informant (7), who felt that 'open source is made of people' and that 'putting the human back into tech' is crucial because humans are the ones who enact care.

6. FOSS is an Open Infrastructure When It Is Open, Political, and Collectivised

Returning to the theoretical framework, infrastructures are ecological and relational, not just 'things' but systems built by programmers. The empirical data of the epistemological encounters and conversations at conferences the past year illustrated how some of these programmers do not make a non-commercial or commercial distinction in the usage of FOSS or open source. Some view open source as 'pragmatic computing' that upholds an 'existing regime of value such as liberalism' which, in this way, instantiates Coleman's political agnosticism (2004: 511–512). For others, open source is considered a 'pragmatic methodology' set against political ideology and activities of F(L)OSS that was viewed as 'distasteful, unappealing, and ineffective' (Coleman 2004: 512). Or, phrased differently, instead of code being 'buggy,' it is politics that needs to be 'tweaked' as it is neither productive nor immediately

8 The term 'maintain-ability' builds upon feminist STS scholar Donna Haraway's term 'response-ability.'

9 A reference to Fernand Braudel's concept of the *longue durée*—a scale of historical reckoning that exceeds the lifetime of a historian or a singular event.

gratifying and instead works against true forms of free thought as it is a 'tainted action clouded by ideology' (Coleman 2004: 513). This echoes Kelty's research that argued that those involved in the movement 'share practices first, and ideologies second' (2005; 2008; 2013). However, as Coleman cogently pointed out, whether acknowledged or not, or even disavowing politics, 'the technology they make and configure embodies values, and thus acts politically' (2011, 516).

Coleman's research (2004) also demonstrated how the value of a 'utilitarian ethic of openness' enabled FOSS programmers to develop state of the art software, which is only made possible by 'open technical production' and in this manner serves as a 'testament to the power of a neutral political commitment' (510–512). At that time, FOSS was the 'most powerful political movement on the Internet' and was able to 'incentivize openness through privatization' in order to argue against proprietary software, even though those involved spent their free time denying it was political (Kelty 2000: 6 cited by Coleman 2004: 508). However, the fact that anyone can use FOSS and that it can be directed towards economic, political, and personal ends is a positive side-effect of this openness (Coleman 2004: 510). In opposition to proprietary knowledge, openness and transparency are necessary to access, contribute, and modify the code. These values encompass how both FOSS and open-source advocates see programming code as a personal road to creativity and expression, to be built upon by others (Coleman 2004: 511), where 'the ability to tinker, adapt, and improve' eventually facilitates innovation (Birkinbine 2020: 15). Therefore, the conditions of when something is considered an open (knowledge) infrastructure revolves around its openness.

In contrast to a 'hacker aesthetic distaste for politics' (Coleman 2004: 511) of the past, for some informants the value of opennness nowadays is becoming more political. Instead of the hijacking and coveting of open-source code by corporations as the 'power of privilege,' there is another 'reorientation of knowledge and power' (Kelty 2008: 23). In spite of Big Tech corporations (such as OpenAI) attempting to co-opt the term, more recent studies such as Poderi's FOSS videogame (2014) and this chapter demonstrate how the political is still tied up in (open) infrastructures. As one informant (2) observed, 'F(L)OSS has been returning to the mouth of people, as a framework and as an essential,

critical infrastructure,' and adding the 'L' to FOSS resonates with the idea of writing source code as a form of speaking. Certain licenses enable and allow 'free and unrestricted expression of speech,' yet argue that this freedom also means an 'unfettered circulation of thought, expression, and action' (Coleman 2004: 510, 512). These political arrangements, or the specific political visions underlying FOSS initiatives, shape both the degree and the form that openness can take.

The informants also explained that if code is politics then the 'source code is a prescription for political action, one that can be encoded into organization form' (McInerney 2009, 2010). For Coleman, one of these organisational forms is 'cultural practice,' which can be mapped onto material actions (2004: 511, 512). These material actions encompass the interplay between the structural and functional aspects of FOSS and open source and when it is considered an open infrastructure, which might be the same on a technical level but on an ethical level, it's a completely different discussion (1). Upon closely examining the nexus between the technical and the ethical dimensions, the organisational and social elements inherent to F(L)OSS initiatives determine the political and governance conditions that allow it to be enacted as such. Therefore, besides openness and politics, it is about the organisational form of governance: as one informant (11) put it, 'F(L)OSS is a commons,' because 'infrastructure is software and lines of commands with hyperscalability' and in this way, it is always 'collectivized'. This echoes another informant's statement that 'code is knowledge' (4) and another expressed how F(L)OSS/open source is an open knowledge infrastructure by defining it as a centre of learning: 'open source is a university, and brought into the community, for better or worse' (10).

7. Recursive Publics

> We are doers [...], we are not weak, we are not lost. Some of us are shaping things (4).

Building upon infrastructure studies and FOSS/open-source literature, the informants have revealed some of the values (pragmatics and openness), ethical and organisational considerations (care and commons) and politics (or lack thereof) imbedded within developing open-source projects, demonstrating how and when F(L)OSS can

be deemed an open (knowledge) infrastructure. In detailing these complexities of software production, the most unified value for people who code is openness, that is:

> a practice and a concept on which recursiveness depends: If one cannot access and see the software and protocols, if they are not open, this particular public cannot exist (Kelty 2005: 186–187).

Recursive, then, is not only a technical term referring to making, modifying, and maintaining, but also describes the 'depth of the technical and legal layers,' because 'geeks' not only argue about technology but through it (Kelty 2008). Following Kelty, these F(L)OSS programmers are intertwined with their socio-material assemblages and thereby recursive because they are 'vitally concerned with the material and practical maintenance and modification of the technical, legal, practical, and conceptual means of [their] own existence' (2008: 3). In this manner, open-sourced code becomes an open (knowledge) infrastructure through which those ideas (and new ones) can be expressed, continuously and recursively.

However, not without humans, yet.

Unexpectedly, with an informed 'ethnographic sensibility to the data collection and analysis' (Star 1999: 383), during the labour of coding the data and writing this chapter (Kelty 2008), the question arose whether the informants in this study could also be considered a 'recursive public.' These 'geeks' are (still) spending a lot of time making, coding, building, compiling, patching, redistributing software code and networking technologies—activities that function as conventions of practice within these communities. Viewed as a 'recursive public,' it became clear that many informants were concerned with ethical dimensions: who controls and who builds the means of political participation and how this becomes an open infrastructure. The right to write software is a way of 'becoming public as it is with any given public debate' and to state an opinion (Kelty 2008: 112, 187):

> In other words, in the process of actively contributing to FLOSS projects, FLOSS programmers actively create, recreate, or reproduce the infrastructure that enables their activity to take place (Birkinbine 2020: 39).

Knowledge and expertise are shared and created within the community to maintain, repair, and regenerate the infrastructural conditions in which they operate and some of FOSS developers (informants) 'see themselves

as part of political movement' (McInerney 2009: 2015). This engenders Star and Ruhleder's parameters of 'embeddedness in infrastructure' and code 'learned as part of membership, or community', because FOSS is an ecology—it is about the relations and the people who make it happen.

> F/OSS is no longer just computer code; it becomes an object around which actors can mobilize and make critical claims (McInerney 2009, 2010, 2015).

Invented and coded technologies, which include all aspects of diverse infrastructures that hold up the internet, as well as future innovations, will continue to be disputed through the lens of what is made proprietary and how this will affect open repositories and their production. However, FOSS consists of people who enact this care, because, as articulated by one informant, 'it is an infrastructure of care that cares about the computational infrastructure' (4). Everyday material practices of F(L)OSS are often unpaid and are carried out in free time, with other commitments and toils overlooked, yet creative and autonomous individuals are working together to forge a more just society by building open (knowledge) infrastructures.[10] Along with this, many informants viewed their role as carrying out the technical practices of FOSS through discursive argumentation, promoting a 'subversive commoning' that recognises commons-based movements that seek to subvert capitalist logics (Birkinbine 2020:114). Free and open-source software is then an open infrastructure that is essential for society as it enables participation, yet society should be the one regulating access to FOSS infrastructures, not corporations. FOSS is then revealed as an open infrastructure reflecting not only a technology but human activity—an entanglement of knowledge, society, and politics.

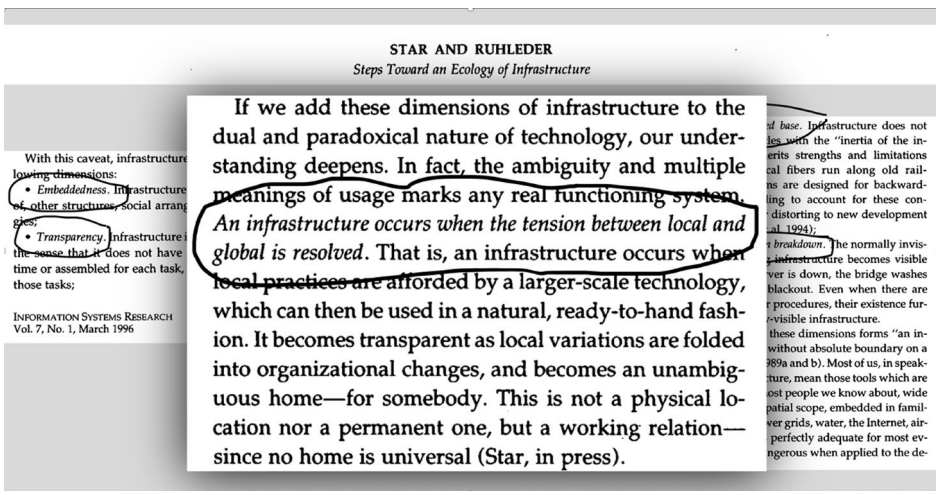
8. Concluding Thoughts

This chapter's objective has been to examine the societal, political, and ethical conditions under which FOSS can be considered an open (knowledge) infrastructure. It has explored the power relations,

10 The article 'Why Do People Give Up FLOSSing? A Study of Contributor Disengagement in Open Source' shows some of the reasons why people contribute to FLOSS/open source in the first place, as well as the reasons for their disengagement (2019).

governance, and a range of F(L)OSS and open-source values, attempting to address all the shifts in terminology and complicated in-betweenness. Throughout the chapter, the Free Software movement of past decades resurfaces through the makers/practitioners of today, who, as a recursive public (Kelty 2008), elucidate how openness, politics, and collectivised action is necessary to build the techno-infrastructures of F(L)OSS. However, for some, Free Software and open source no longer mean, or do, the same thing (Kelty in 2013), with the informants putting forth different values and ambiguities that characterise the plurality of political and ethical views. As shown above, the discussion still continues and, depending on who you talk to, open source itself is still 'an instrumentalized kind of politics,' and as Kelty notes, along with that, 'the possibility of new beginnings fades' (2013). Although the critical power of open source was its 'potentiality,' its modifiability and openness, the 'once beloved power to "fork" the software [often] disappears in a world where centralized infrastructure is everything' (Kelty 2013).

Returning to the emergence of infrastructures and relational ecologies, what Star did not include in her properties was Star and Ruhleder's final dimension: 'An infrastructure occurs when the tension between local and global is resolved' (Figure 2.2).


STAR AND RUHLEDER
Steps Toward an Ecology of Infrastructure

If we add these dimensions of infrastructure to the dual and paradoxical nature of technology, our understanding deepens. In fact, the ambiguity and multiple meanings of usage marks any real functioning system. *An infrastructure occurs when the tension between local and global is resolved*. That is, an infrastructure occurs when local practices are afforded by a larger-scale technology, which can then be used in a natural, ready-to-hand fashion. It becomes transparent as local variations are folded into organizational changes, and becomes an unambiguous home—for somebody. This is not a physical location nor a permanent one, but a working relation—since no home is universal (Star, in press).

With this caveat, infrastructure
lowing dimensions:
• *Embeddedness*. Infrastructure
of other structures, social arrang
gies;
• *Transparency*. Infrastructure i
the sense that it does not have
time or assembled for each task,
those tasks;

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d base. Infrastructure does not
les with the "inertia of the in-
erits strengths and limitations
al fibers run along old rail-
ns are designed for backward-
ling to account for these con-
distorting to new development
al, 1994);
breakdown. The normally invis-
infrastructure becomes visible
ver is down, the bridge washes
blackout. Even when there are
procedures, their existence fur-
-visible infrastructure.
these dimensions forms "an in-
without absolute boundary on a
89a and b). Most of us, in speak-
ture, mean those tools which are
ost people we know about, wide
patial scope, embedded in famil-
ver grids, water, the Internet, air-
perfectly adequate for most ev-
ngerous when applied to the de-

Fig. 2.2 Star and Ruhleder's *Steps Towards an Ecology of Infrastructure,* with a new dimension added (1996), annotated by the author of this chapter.

The Linux operating system mentioned above by the informants is an 'open infrastructure' that provides a material basis for the 'massively decentralised and collaborative production occurring within FLOSS production' (Birkinbine 2020: 39-40). Nowadays this could be applied to how virtually every computer worldwide runs on open-source software, which is a 'critical infrastructure that enables the Internet to function' (Birkinbine 2020, 10). However, as Star already realised in 1999, (open) infrastructures are 'big, layered and complex' and 'nobody is really in charge' and (usually) 'not changed from above,' yet local repercussions differ. As observed during the writing of this chapter, the global company CrowdStrike's blackout in July 2024, which became visible upon breakdown, was not about sustainability but 'maintain-ability' (10) or even 'update-ability.' During the scheduled update, millions of computers worldwide were switched on because they were running Microsoft Windows, which was partially built on open-source code but is now proprietary and incompatible with Linux or Apple OS. Perhaps if CrowdStrike's Falcon cybersecurity software was fixed (or updated) in modular increments, not all at once or globally, as Star elucidated in 1999, it wouldn't have resulted in the most extensive (and costly) worldwide IT outage in history so far.

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3. The Internet Infrastructure Has Never Been Open

Niels ten Oever[1]

In this chapter, I argue that openness offers a limited view, and surely not access, into closed systems. The following analysis demonstrates how openness is always a matter of openness for a particular group, namely, the group that can set and alter the configuration of the material infrastructure. Openness, then, is not a neutral design principle but an expression of infrastructural power, of who gets to define, design, and delimit participation. This group's interests may coincide with those of other groups, but when these interests are at odds, the interests of one group prevail over the other. I will analyse how the internet has been open to different groups, namely the military, business, intelligence services, the state, academia, and users. I conclude by demonstrating how the internet has been particularly open to configuration by the US military and industry, and how the essence of openness is located in its limitations.

Openness is liberalism's favourite paradigm. It emerged in response to the perceived 'closedness' of the so-called Second World during the Cold War (Edwards 1996). In the development of the precursor to the internet, which was initiated by the agency established in response to the Soviet Union's launch of Sputnik, openness took a central place. It stuck and became a guiding principle in the development of digital networks (Russell 2014). Openness meant many things simultaneously

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in the development of the internet: open protocols, open archives, open participation, and the ability to expand the internet network (ten Oever 2021). With the success of the internet, the concept of openness gained momentum. It first spread to directly related fields such as open-source software, and from there, it continued to expand. It began with concepts still closely tied to computing, such as OpenStreetMap and Wikipedia, and later expanded to broader initiatives, including open government and open-access publishing.

Science and technology studies (STS) over the past few decades have done excellent work in showing that every field, practice, and technology harbours power structures, hierarchies, and excludes people, beings, and practices. What I would like to contribute to the academic debate in STS and infrastructure studies is a reflection on how general-purpose infrastructures do not exist. I argue that openness can exist in infrastructure, but that it will always be openness for a particular group. Uses that go against that will be deprioritised, antagonised, and eventually written out.

While the concept of inscription is by no means new, Akrich (1992: 208) described it as 'the work of innovators [which] is that of "inscribing" this vision of (or prediction about) the world in the technical content of the new object', and the idea that such inscriptions may serve the interests of particular groups over others has already been articulated by Callon (1990: 143). This perspective is crucial for understanding openness not as universal access, but as the outcome of selective inscription by powerful actors. It underlines that infrastructures are relational. They are not solely shaped by material technologies, but also by the epistemic communities, institutions, standards, practices, and protocols that co-constitute them (Star and Ruhleder 1994). Nevertheless, because of their scale, complexity, technical opacity, and deep entrenchment in everyday life, infrastructures often remain beyond the reach of public scrutiny (Peters 2015).

Aside from the lack of scrutiny, infrastructures commonly undergo discursive examination through the analysis of myths (Mosco 2005; Bory 2020), narratives (Breuer and Johnston 2019; Hofmann 2020; Lambach and Oppermann 2022), and socio-technical imaginaries (Jasanoff and Kim 2015). There is, however, a risk of overly relying on discursive representations and analyses without coupling them with a careful

analysis of the material ordering–potentially perpetuating a discursive image that legitimises a particular ordering without describing its technical workings and material control (ten Oever 2023).

Open for the Military

When Sputnik was launched, it was not the satellite over which the world marvelled that scared the United States; it was the intercontinental ballistic missile that carried it. Sputnik was perceived as a dummy payload to distract from the material threat, much like platforms, APIs, and interfaces distract from the sedimented infrastructural power that underpins them. The infrastructural anxiety induced by the *tour de force* of the Soviet Union, which demonstrated its military and scientific supremacy, prompted the United States to respond institutionally by establishing the Advanced Research Projects Agency (ARPA).[2] This agency's first two projects and priorities still echo today: the establishment of NASA and the ARPANET, a network that could withstand a nuclear strike.

Computers had already been deeply written into the war effort: the ENIAC computer had been doing calculations for missile trajectories (much like Galileo Galilei's gunner compass had done nearly four centuries before), and the Bombe machine was used to decipher German communications. However, all these calculations would be worthless if they were not communicated. It was already clear that a vast computer network could function not merely to send calculations, but also to work like a nervous system, connecting radars, command centres, and both conventional and nuclear weapons in a system to defend the United States against Soviet threats (Edwards 1996). In these labs, machines and scenarios were devised for possible 'dead hand' scenarios where the US would retaliate against a Soviet nuclear strike, even in the case of impact, to ensure mutually assured destruction. The internet had the promise to connect all efforts, increase its resilience, and allow for better coordination.

Towards the end of the Cold War, military funding gave way to increased research funding, and after the fall of the Soviet Union, to commercialisation. Scholars like Madeline Carr argue that, at that

2 Currently known as the Defense Advanced Research Projects Agency (DARPA).

moment, US military power made way for US commercial power (Carr 2015). However, what often remains under-explored is the enormous power the US military still holds over the internet, both directly and indirectly.

In earlier communication networks, such as telecommunications, connections were always tied to a particular geography due to the underlying technology, namely circuit switching. The internet functioned as an overlay network and could therefore function over all kinds of networks. The concept of the 'borderless internet' suddenly provided the US military with access to many places around the world through a territory it had itself co-designed. When NATO officially declared cyberspace as a domain of warfare in 2016, the United States military was back in a place it had never left. A few years later, NATO would also assign space as a domain of military warfare. The two ARPA projects had been delivered.

In nearly all definitions of the internet, the internet protocol (IP) is the connecting denominator. For over twenty-five years, we have known that IPv4 addresses are running out, and the Regional Internet Registries are no longer allocating them. At the same time, the US military controls 13 /8 blocks of IPv4 addresses, in other words, 221,828,864 IPv4 addresses, which is roughly six percent of the total number of public internet addresses, most of which are never used but are kept as a strategic stockpile.

To summarise, the US military has been one of the founders of the internet, has influenced its design goals, shaped the internet, sees the internet as a military domain, and still holds a significant amount of the internet's primary resources. The military's infrastructural authorship exemplifies how openness operates: it is open to those who design and command the system, while these options are closed to those who merely use it. In this sense, the internet's earliest openness was an openness for military coordination, not public participation.

Open for Industry

The reconfiguration of communication infrastructures by the internet has led to a significant reshuffling of power from telecommunications providers to content providers. The erstwhile end-to-end philosophy

of internet engineering transformed the network from a data control network into a data transport network: '[t]he network's job is to transmit datagrams as efficiently and flexibly as possible. Everything else should be done at the fringes' (Internet Architecture Board 1996: 2–3). The new emphasis on end-to-end connectivity took power and control over data streams from the network, and promised to give it to the end-devices, thus communication infrastructure transformed from smart networks with dumb phones, to a dumb network with intelligent computers, taking away power from network operators and handing it over to endpoints.

In the tussle over control of data streams between network operators and content providers, power was never handed to end users, only to the servers of the content providers. The end-to-end connectivity turned out not to be symmetrical between all ends because not all endpoints were created equal. While people's end-devices had sufficient capacity to run their mail servers and websites, network directionality was introduced, and third-party services for email, social media, and website hosting were offered, whereas these could architecturally just as well have been hosted on end-user devices. The concept of the user was produced through the infrastructure. That the internet infrastructure was open for business meant that the end-user became a customer and a data producer, and subject to endless varieties of data extraction.

Initially, the infrastructure was monetised through simple ads, but this swiftly developed into a sprawling and intricate ecosystem of advertisement technology, including cookies, tracking, and real-time bidding on individual user profiles. The leader in this industry was and continues to be Google, through its AdSense platform (now Google Ads). It firmly galvanised this position by maintaining the world's largest browser (Chrome), and a large content offering through search, email provision (Gmail), and content provision (YouTube).

To offer content as fast as possible, whilst allowing advertisers to engage in real-time bidding and serving personalised ads with as little friction as possible, Google developed and implemented its own encrypted transport protocol called QUIC (Quick UDP Internet Connections) in 2012. Many had tried this before, but only Google was able to do so because of its ability to do experimental testing on the internet between the world's largest browser and its extensive server network (Perarnaud and Musiani 2025). This standard was brought to the Internet Engineering Task Force

(IETF) in 2015 because if this protocol were standardised and accepted as the primary new transport protocol of the internet, no one in their right mind would block it, which might not be the case if it were 'only' Google's protocol. In 2016, a working group was established in the IETF, and in 2021, the formal QUIC standard was published as RFC9000 (Iyengar and Thomson 2021).

This reconfiguration of the internet infrastructure occurred quite rapidly and with minimal discussion. It was clear that Google had successfully brought together the interests of many different content providers in the development of this new protocol. What is presented as infrastructural openness through open protocols, interoperable standards, and open processes was, in practice, an opening for industry to consolidate control. The internet thus remained open, but only to those with the capacity to inscribe their economic and infrastructural power into its standards. The combined interests were illustrated when a review was done on the potential human rights impact of QUIC,[3] which was presented at the meeting of the Human Rights Protocol Considerations Research Group (HRPC) in 2018 in Bangkok.[4]

Open for Civil Society

A couple of civil society actors from the organisations ARTICLE 19, Coding Rights, and the Association of Progressive Communications (APC) started addressing human rights considerations in internet protocols in November 2014 by giving a presentation to the Internet Engineering Task Force (IETF). This resulted in the establishment of a dedicated research group in the Internet Research Taskforce in 2015 (Cath 2021) and the publication of a dedicated methodology to engage in the review of internet protocols and their human rights impact (ten Oever and Cath 2017).

The human rights review of the QUIC protocol was based on seven 60–90 minute elite interviews with QUIC working group leadership, main document authors, and active participants in the development of QUIC, conducted using a method specifically devised for this purpose

3 See https://datatracker.ietf.org/doc/html/draft-martini-hrpc-quichr-00
4 See https://youtu.be/Bd33Be_P-FY?si=4N-NokjnNYLNa1Jc&t=5286

(ten Oever and Cath 2017). The results of the QUIC analysis were relatively mild, with some concerns regarding risks to consolidation in the internet architecture, privacy, internet transparency, and internationalisation. However, the critique of the human rights impact assessment of the protocol received was fierce; the first commenter, a member of IETF leadership, contended that the review 'did not add anything to the discussion.' Several members of the Internet Architecture Board (IAB) and even the IETF chair came out to denounce the work. The latter even added that 'just participating in working groups would be far more efficient than writing these broad-based external reviews and just coming in from the outside.'[5] The critiques offered in the session diverged (ranging from claims that the review was conducted too early to analyze the impact of the QUIC protocol, to assertions that it cametoo late in the development process to contribute to the development meaningfully; that all issues mentioned in the review had already been discussed; that the analysis was technically incorrect; and, conversely, that it was technically correct but still irrelevant). Yet despite these shifting objections, no concrete errors in the review were identified in person or posted to the mailing lists of the QUIC working group or the HRPC research group. The review, however, did have a different impact, namely, an extensive discussion in the IAB about whether the HRPC Research Group should be closed and disbanded. This was averted by the external appointment of two technical advisors to the research group in March 2019, something that had never happened in the IRTF or IETF before.

As of 2026, HRPC has organised sessions at the IRTF for ten years,[6] but participation and mailing list activity have decreased significantly. The only moment a concrete, meaningful influence on protocol development was achieved was when Verisign, the largest internet registry, most known for its management of the .com and .net domains, made a proposal.[7] This proposal would facilitate the alignment of the Extensible Provisioning Protocol (EPP) with a Chinese draft law[8] by offering the

5 See https://youtu.be/Bd33Be_P-FY?si=zy3nKBNHGviPCb2M&t=6228
6 See https://www.ietf.org/proceedings/95/hrpc.html
7 See https://datatracker.ietf.org/doc/html/draft-ietf-regext-verificationcode-06
8 See https://chinacopyrightandmedia.wordpress.com/2016/03/25/internet-domain-name-management-rules-opinion-seeking-revision-draft/

possibility of a Verification Service Provider (VSP) that would check the identity of someone who wanted to register a domain name. A review of the human rights impact of this proposal was made[9] and concluded that 'the proposed extension in its implementation allows the VSP to have enormous censorship and discriminatory power. The arbitrary and opaque mechanism to "verify" compliance with local regulations gives disproportionate powers to impede freedom of expression, right to privacy, freedom of association, and the right to non-discrimination.'[10] After a lengthy discussion, the working group began to agree on adding privacy and human rights considerations to the document, but suddenly, Verisign decided to abandon further development of the document.

The pattern that emerges from the example of QUIC and EPP shows that civil society engagement is tolerated when it brings up issues that do not necessarily align with US interests (in the case of EPP, which helped align the internet infrastructure with the Chinese legal system), but when it does so against the interest of the US (as happened in the case of QUIC), it is made clear that it has no place to inscribe its values.

In their respective works, from very different angles, Madeline Carr (Carr 2013), Jeanette Hofmann (Hofmann 2020), and Corinne Cath (Cath 2021) show how the voices and interests of civil society actors are welcomed in internet infrastructure governance, as long as their stances align with those of other stakeholders and legitimise the institutional ordering, otherwise, their standpoints are disregarded. Civil society actors could participate, but not configure; they could speak, but not inscribe. Their openness was conditional and revocable, illustrating that participation without infrastructural power reproduces the very exclusions that openness claims to overcome.

Open for Intelligence

In 2013, the Snowden revelations showed the world how the United States (US) and the Five Eyes collective, comprising Australia, Canada, New Zealand, the United Kingdom, and the US, collaborate to use the internet for signals intelligence. In order to do this, they leverage both

9 See https://gitlab.com/hr-rt/documents/-/blob/master/HR-RT%20Review%20of%20draft-ietf-regext-verificationcode?ref_type=heads

10 Ibid.

the infrastructure and its chokepoints (Tusikov 2016), as well as access to large infrastructure and service providers. Through the so-called Prism programme, the US National Security Agency (NSA) would have direct access to the servers of Google, Microsoft, Facebook, and Apple, and by weakening cryptographic standards, it would be able to decode data streams directly (Rogers and Eden 2017).

The collaboration between state and corporate surveillance facilitated the production of an infrastructure of extraction (Zuboff 2020; Cohen 2019; Jung 2025). The joint redesign that optimised the internet infrastructure for extraction might be compared to the redesign of Paris by the architect Haussmann (Soppelsa 2009). The broad boulevards provide the possibility, access, and overview for police and authorities, making it easier to read and control the city, and to suppress riots. But the design would also prove to work great for trucks and commerce. One thing was certain: barricades could not be easily erected, and anonymous congregations would be nearly impossible. Intelligence agencies' ability to repurpose the infrastructure for surveillance again demonstrates that openness serves those who command the chokepoints. The infrastructure's supposed neutrality concealed its deep alignment with state power. The logics of security and profit both demand selective openness: enough transparency to sustain innovation and connectivity, but sufficient closure to enable monitoring and monetisation. Extraction depends on predictable, measurable flows of data, which are only possible within infrastructures that are open enough to connect but closed enough to control. In this sense, the internet's transformation mirrors the reconfiguration of public space: what once promised a commons for exchange and assembly has become a tightly managed environment where participation is continuously monitored and monetised.

Open for the State

In the current geopolitical moment where the US is retreating from international norms, we witness something that can be compared to an infrastructural breakdown (Star 1999), but not in the sense that the internet infrastructure is not working. Rather, it is not working as many governments expected. Many governments around the world are experiencing the

infrastructural anxiety that the US experienced with the launch of Sputnik. In response, states are trying to erect barriers, but are noticing it is not easy to do so on a network that 'does not recognise borders.' Countries and regions are dusting off old strategies of industrial policy, but are having a hard time fitting them within the neoliberal ideologies of our times, where the government is generally understood as inefficient in comparison to the market as a structuring and organising mechanism. Notions of strategic autonomy and digital sovereignty collide with the inertia of infrastructures built on the concrete foundations of the Cold War.

Within the European Union, the concept of the 'EuroStack' is having its political moment.[11] However, as of writing, nowhere has it been significantly explicated what would differentiate a European Stack from a non-European Stack (because they should be interoperable through open standards), except that small and medium-sized enterprises would produce it. What adds insult to injury is that there seems to be no plan to prevent these European companies from being acquired by US capital, or for US Big Tech or its subsidiaries to participate, because otherwise the EU would violate its own rules for free market competition. This is precisely what was witnessed in the previous European digital sovereignty initiative, Gaia-X (Baur 2024).

EuroStack aims to enhance European competitiveness by developing European supercomputers and AI factories, thereby propelling its industry into a competitive race with the US and China. It is difficult to grasp this logic: how can one be expected to win a race that others began long ago, with larger budgets and far greater industrial and societal absorption capacity? Europe is struggling with the paradox of wanting to be both open and autonomous at the same time. It is therefore not surprising that European defence contractors, such as Thales and Airbus, see a role for themselves in defending European interests.

At this point, it becomes clear that alternative technological trajectories highly depend on military spending—a point also highlighted by Mazzucato (2018), who proposes developing more civil missions. Together with Eaves and Vasconcellos, Mazzucato contributes

11 An in typical European fashion, the initiative already seems to be split into two camps and three documents: https://www.euro-stack.info/docs/EuroStack_2025.pdf, https://euro-stack.eu/a-pitch-paper/, and https://euro-stack.eu/the-white-paper/

to a notion of digital public infrastructure (Eaves et al. 2024), which can be characterised at its best as uncritical. In their report, the authors equate openness with publicness, which, as we have shown before, does not at all account for power differentials in infrastructures. The critique against the digital public infrastructure project is not merely theoretical. As the critical work by Nai Lee Kalema shows, the coercive politics of digital public infrastructures have taken form (2024).

The state's renewed infrastructural anxiety exposes the contradiction at the heart of openness: to be open to all is to be vulnerable to those with greater power. The European search for 'sovereign openness' thus reveals that openness itself is a terrain of geopolitical struggle.

Freedom in Limitation: Demilitarised Infrastructures and Public Services

The international use of the word 'infrastructure' started with the communique of the NATO meeting in May 1952, which read: '[a]greement was reached on the financing of a further portion of the infrastructure program, for airfields, communications and headquarters.'[12] The history of the internet and telecommunications is deeply characterised by its use by police, military, and intelligence agencies. In physical space, it is very clearly observable where the space is public, private, or military; the internet, however, is always private and military.

Creating a communication network that functions as an open infrastructure would mean limiting its scale and use to protect users from coercion, control, extraction, and capture. It would mean undoing the excommunication of the user from the design and control over the network, and reintroducing them as citizens who would be able to observe, contest, and configure the network in meaningful ways (Galloway et al. 2013; ten Oever 2023).

If the study of power in infrastructures teaches us one thing, it is that infrastructures cannot simultaneously be open and equally accessible to all groups at the same time. If there is a future for open and sustainable civilian infrastructures, the core property should not be abundance, but limitation and distribution (ten Oever 2025).

12 See https://www.nato.int/docu/comm/49-95/c520225a.htm

Understanding openness as always situated and partial allows us to imagine infrastructures differently; not as systems open to everyone in the abstract, but as deliberately limited commons that protect against domination. Genuine openness, paradoxically, may lie in collective limitation: infrastructures that refuse universality to sustain equality.

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II. OPENING GOVERNMENT DATA INFRASTRUCTURES

4. Infrastructuring Openness: Austrian Practices and Politics of Opening Up Government Data

Astrid Mager

Introduction

I'm sitting in a traditional Viennese coffee house, the Café Prückel. It is early May and bright sunlight falls into the large windows of the spacious, art nouveau café. I am waiting for my interview partner, who is one of the key figures in creating Austria's data strategy. While preparing for the interview, I think how funny it is to talk about digital futures in a space that was built one hundred years ago, in a space where a wide range of newspapers is laid out and digital payment was introduced just recently. Time seems to stand still in this place. When my interview partner arrives, I am taken out of my thoughts and into the topic of our conversation: the datafication of governmental affairs. One of the first things my interviewee says is that we are meeting at a 'revolutionary' point in time since a new law has just been passed in Austria, the Freedom of Information law. When this law goes into force in September 2025, a long-standing feature of Austrian bureaucracy will be abandoned: 'professional secrecy' (Amtsgeheimnis). The concept of professional secrecy goes back to the enlightened absolutism of the Habsburg monarchy (eighteenth century onwards) and was codified in 1925. While Austria had preserved a culture of secrecy in bureaucratic practices and procedures dating back to the time of the monarchy, the

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world of data has tremendously changed, and Austria's bureaucracy is now expected to follow.

The Freedom of Information law requires the proactive sharing of data on the side of the state and the right to data access on the side of citizens—something that fundamentally challenges Austria's bureaucratic tradition, built on secrecy rather than transparency. The policy maker I am interviewing refers to a cultural shift that the implementation of the law will trigger in practice: 'This should have an enormous impact on the data culture in Austria, in my view. I think the public sector will have to learn a lot about the handling of data. This is positive because I see that the mandatory opening up of data, the proactive duty to provide data, will change a certain mentality in administration.'[1] This statement points right to the heart of this chapter, the cultural, practical, and political dimensions of opening up government data in Austria—or the 'infrastructuring of openness,' as the title suggests, a reference to research that has conceptualised digital infrastructure as a process rather than an object (Karasti and Blomberg 2018; Musiani 2022; see also Chapter 6 in this volume).

In our conversation, the policy maker defined three central steps in the actual implementation of Austria's data strategy: 1) building data infrastructures, 2) increasing data use, and, most fundamentally, 3) establishing a new 'data culture,' as he called it. How to practically achieve these goals, what challenges and controversies arise, and how to foster a more collaborative data culture will be discussed in this chapter by shedding light on three government data infrastructures in Austria: 1) the open government data portal data.gv.at, which provides non-personal data for free, 2) the Austrian Micro Data Center, which provides restricted access to sensitive administrative data for research purposes, and 3) the digital geoTwin of the city of Vienna, a 3D model of the city, intended to integrate different data sets in the future. While these data infrastructures fundamentally differ in terms of their degree of open-/closedness, data types, and access, as well as target groups, they all share the ambition to open up government data for secondary use—through initiatives such as creating open data applications, facilitating micro data research, or fostering data-driven city planning, as will be

1 All German quotes have been translated by the author.

discussed in the following pages. To account for these differences, I speak of different ways of 'opening up' government data rather than open government data, which would exclude the Austrian Micro Data Center providing highly restricted access to government data. It would partly also exclude the digital geoTwin, which is a kind of hybrid on the continuum between open and restricted government data since there is one version of the geoTwin that is open to the public and one version that displays more sensitive data for internal use only.

This chapter proceeds by tracing the history of open government data approaches and positioning it within the wider context of the neoliberal 'data welfare state' (Dencik and Kaun 2020; Dencik 2022; Kaun and Masso 2025). After providing a brief overview of the three government data infrastructures, I dive into the multi-faceted practices and politics of infrastructure building, data sharing, and cross-organisational collaboration. To conclude, I will situate Austrian attempts at infrastructuring openness within contemporary trends of EU data policies, and discuss how to foster a more open, participatory, and collaborative data culture in the context of wider transformations of the data welfare state.

The Push Towards Open Government in the Data Welfare State

In the early 2000s, non-governmental actors started to pressure governments to pro-actively share non-sensitive data and make them freely available to use, reuse, and redistribute without any legal, technological, or social restrictions.[2] In this context, open government data were seen as central in generating a collaborative dialogue between policy makers and citizens (Broomfield 2023). In 2009, Barack Obama pushed open government as a political agenda, with his open government strategy comprising three central pillars: transparency, participation, and collaboration.[3] In the European Union, open government has been on the agenda for more than twenty years now, starting with its 'eEurope'

2 See the Open Definition by the Open Knowledge Foundation: https://opendefinition.org/od/2.1/en/

3 See https://obamawhitehouse.archives.gov/open

action plans that included e-government (EC 2000). The willingness to open their governments, however, varies considerably between European member states because of cultural differences and divergent understandings of the role of government. Traditionally, Northern European countries are considered to be at the forefront of opening up government data for secondary use (Götz and Marklund 2015). Contrary to these 'information-friendly' democracies, the political culture of Austria has been described as 'information-restrictive' by Parycek and Schossböck (2015) since the flow of information between the authorities and citizens follows a 'push principle,' with the authorities controlling access and distribution of information—thus undermining free information as a basis for participation. Parycek and Schossböck (2015: 219) concluded that 'the historical background with a longstanding culture of closure, state sovereignty, and the attributes of the Habsburg bureaucracy has played a significant role for this.' This not only impacts the balance between open government and governmental secrecy in public debate, as the authors discuss, but also hampers practices of opening up government data, as we will see in the analysis below.

Open government data have traditionally been linked to notions of openness, transparency, and accountability (Baack 2015; Schrock 2016; Redden 2018). In this context, citizens, often activists, are framed as active agents and co-producers of knowledge, policy action, and governmental activities (Baack 2015). Non-state actors such as civil society actors, journalists, programmers, hackers, but also start-ups and other innovators are seen as 'open government data intermediaries' (Schrock and Shaffer 2017) that help to make use of open data by creating apps, infographics, dashboards, and the like. They have been described as central actors who increase 'the utility of data, move it throughout a data ecosystem, and serve a democratizing function' (Schrock and Shaffer 2017: 2). Critical research, however, has shown how open government data policies have been strategically used to continue the neoliberal form of state—the marketisation of public services and the privatisation of public assets, in particular (Bates 2014; see also Powell 2021: 83ff). Over the past decades, state institutions have been remodelled through new public management techniques to provide their services more efficiently while saving costs due to the pressure of resource scarcity. The datafication and automation of welfare services have been embraced as central tools to arrive at this

goal—a trend that has been captured with the notion of the 'data welfare state' (Dencik and Kaun 2020; Dencik 2022; Kaun and Masso 2025). The data welfare state strongly relies on datafication, a 'process whereby numbers are turned into datasets that, collectively, provide information about behavior' (Andreassen, Kaun, and Nikunen 2021). Dencik (2022) speaks of the 'datafied welfare state' in this respect (see also Van Dijck (2014) on 'dataism' more generally). A growing body of research has shown how datafication and automation can result in citizen surveillance, algorithmic bias and discrimination, as well as crucial transformations of citizen-state relations (Dubois et al. 2018; Allhutter et al. 2020; Sztandar-Sztanderska and Zieleńska 2018; Dencik and Kaun 2020; Dencik 2022). Moreover, questions of data justice arose in the context of the COVID-19 pandemic, where datafication led to social inequalities due to lack of data on marginalised groups (Milan 2020; Madianou 2020; Pelizza 2020), most particularly in the Global South.

Critical research has further shown that EU data policies increasingly conflate open government data with the reuse of public-sector information, the latter of which is rooted in the digital economy rather than citizen empowerment. Having analysed the EU's Open Data Directive (ODD), Broomfield (2023) argued that the two distinct concepts of open data and the reuse of public-sector information (PSI) have been 'married' in the directive despite their fundamentally different origins. The reuse of PSI is 'firmly rooted in the realization of the European data economy, while open data is primarily anchored in ideas around government transparency and accountability as a way to facilitate citizen participation' (Broomfield 2023: 186). Broomfield (2023) concluded that principles of open data are somewhat integrated in the ODD, but that references to citizen participation tend to be reduced to acts of 'window dressing.' This confirms older research that discussed the process of opening up government information as fuelled by demands for both transparency and accountability and by the commercial reuse of data (Janssen and Hugelier 2013). It also corresponds to contemporary research that identifies a shift in Norwegian policy narratives from the rationale of efficiency and public sector data improving public administration towards the rationale of data-driven innovation, where 'value creation and public sector data sharing with the private sector are central' (Reutter and Åm 2024: 647). These rhetorical shifts may be seen as part of the EU's aspirations to create a data-

driven economy, but also as part of the global hype around datafication, sensorisation, and artificial intelligence (Mettler and Miscione 2022). They may also be seen as pointing to a long-standing ambivalence in European technology policy that Ulnicane (2021) refers to as the tension between Normative Power Europe and Market Power Europe. Having analysed EU policy discourses on AI, the author identifies competing narratives between the 'human-centred approach' to digital innovations and the rhetoric of the EU's economic interests as represented by the notion of the Digital Single Market. Ulnicane (2021) concludes that the EU strongly emphasises Normative Power Europe, while at the same time repeating the competition discourse inherent in Market Power Europe. Tensions between Normative Power Europe and Market Power Europe may thus be seen as being deeply embedded in the EU's open data policies, but also in actual practices of opening up government data, as we will see in the Austrian context.

Opening Up Government Data in Austria

In 2012, the city of Vienna created a metadata portal for open government data (OGD), data.gv.at, in close collaboration with the open data movement.[4] The development, metadata standardisation, and governance of data.gv.at was organised through the open-ended Cooperation OGD Austria that involved the cities of Vienna, Linz, Salzburg, and Graz, along with the Open Knowledge Foundation Chapter Austria, the Danube-University Krems (Center of E-Governance) and the Open3.at association (Höchtl et al. 2014). Data.gv.at provides access to data, figures, documents, and services in formats that are machine-readable, open, and free of charge. As of June 2025, data.gv.at holds 57,728 data sets clustered in topics such as society, health, culture, government, finance, climate, and many more, and displays 750 applications of various sorts—including apps, maps, or infographics. Moreover, the city of Vienna is currently working on a digital geoTwin—a digital 3D model of the city—as a basic infrastructure for a 'real' digital twin that is intended to integrate heterogeneous data sets for simulating future

4 See https://www.data.gv.at/

city planning or climate-related scenarios (Lehner and Dorffner 2020). These data include open data such as geo data that the city collects (street level point clouds or airborne data), sensor data (e.g. air, wind, water), but also factual data from the different city departments (city planning, building, land registry, etc.)—partly shared via data.gv.at, partly for internal use only.

While the data.gv.at platform centralises metadata from public institutions at all levels (federal government, cities, municipalities) that is freely accessible, the Austrian Micro Data Center (AMDC)[5] centralises administrative data only for accredited research institutions and for a relatively high fee. After the COVID-19 crisis—and after increased lobbying by researchers and the Plattform Registerforschung (platform for registry research)[6]—a change of the Research Organization Act (Forschungsorganisationsgesetz) paved the way towards opening up statistical and administrative data for research purposes. To this end, the AMDC was created in 2022 to manage access to sensitive statistical and administrative data for research purposes as part of Statistics Austria. The AMDC holds pseudonymised microdata on individuals and firms from Statistics Austria and the Austrian federal government. Different microdata sets from Statistics Austria, administrative registers, and microdata brought in by researchers themselves can be linked via 'unique pseudonymized identifiers' (Fuchs et al. 2023)—an aspect that elicited a range of differing opinions from my interviewees.

To empirically examine the multi-faceted practices and politics of opening up government data in Austria, I conducted desk research, website analyses, and thirteen qualitative expert interviews (Bogner and Menz 2009) with stakeholders involved in building and governing the three data infrastructures. My interviewees included representatives of the data.gv.at portal, the Open Commons Linz initiative, the AMDC, the Plattform Registerforschung, the digital geoTwin of Vienna, as well as policy makers, open data and digital rights activists, and researchers working with open and administrative data more generally. The interviews were conducted in 2023 and lasted between 45 and 120

5 See https://www.statistik.at/en/services/tools/services/center-for-science/austrian-micro-data-center-amdc

6 See https://www.registerforschung.at/

minutes. They were transcribed and analysed with MAXQDA following a Grounded Theory approach (Glaser and Strauss 1968) that enabled me to code the material along the three research questions from top down, while allowing me to come up with new categories that emerged from the interviews, such as Austria's 'data culture.'

Infrastructure Building and Data Work

Talking about the early days of data.gv.at, one of the founding members said that 'community work' was a central driver for opening up government data in Austria. This work included communal meta-standard setting, quality control, data care and repair, as well as practices of creating apps, infographics, and other digital services—often conducted by intermediaries for free. This aligns with research on large-scale infrastructures showing that infrastructure building is a complex process involving not only technical, but also social and organisational entities (Bowker and Star 2000). Star (1999: 380) framed infrastructure 'as part of human organization' and called for foregrounding the truly backstage elements of work practices. The backstage elements of infrastructure building were highlighted by my interviewees, too. Comparing infrastructure work to 'sexy app development,' one interviewee summarised it like this: 'Quick win for display to make the next press conference work, but the hard digitisation work remains backstage, not seen by anyone for many years. And you won't notice it as long as it works and no one will praise you for something that is invisible.' An open data activist referred to the constant, tedious, and yet invisible 'relational work' that is necessary to fill infrastructures with data, the ongoing task of motivating administrative bodies to share their data in open data formats (despite the 'open by default' guiding principle of the city of Vienna's data excellence strategy).[7] Both the relational dimension of infrastructure building and the invisibility of the multi-faceted data work resonate with central findings from infrastructure studies (Bowker and Star 2000). Zakharova and Jarke (2024: 5) speak of 'care work' in the context of organisational practices, which is needed to

7 See https://digitales.wien.gv.at/wp-content/uploads/sites/47/2020/04/PO19-00224-DigitaleAgendaWien_Ue-en.pdf

build and maintain data infrastructures—'care work that sustains and enables the production, processing, circulation, and use of data.'

Besides the multi-layered 'care work' that is needed internally, there is a great deal of translational work done by actors outside of public administration. One illustrative example that was mentioned by multiple interviewees was a public transport app developed by and for disabled citizens: 'Well, I immediately think of the Verein Bizeps [an association for autonomous living for people with disabilities] that cares about wheelchair users in Vienna. [...] They developed an app showing which elevators work and don't work in subway stations' (open.gv.at representative). This way, the city employee added, public services can be provided that are not covered by the city of Vienna due to their specificity. The Verein Bizeps thus shows how 'open government data intermediaries' (Schrock and Shaffer 2017) make open data productive for citizens and thereby contribute to the provision of welfare services. It further illustrates that applications should be seen as integral parts of the larger ecosystem of open data infrastructures. They enable 'lived participation in the political process,' as an open data activist concluded in the context of apps that enable residents to report damages in the city and follow how they are resolved by the city administration. While such quotes evoked classical ideals of open government such as transparency and participation, more critical aspects were raised regarding the corporate use of open data. Contrary to the idea of putting apps that use open data on the data.gv.at portal, a city employee bemoaned that many industry actors would take open data to build their commercial apps without feeding them back to the portal, following business models that resemble acts of information commodification (Bates 2014). At the same time, companies hold valuable city data locked up in closed infrastructures. An open data activist therefore concluded that e-scooter companies, for example, should be pressured to share their data if they are allowed to provide their services in the city. Such quotes allude to the economic rationale undermining not only data policies, but also actual practices of opening up and aggregating data, as will be further discussed in the next section.

Practices of Data Aggregation

My interviewees agreed that the integration of different data sets adds value to government data. Just like the 'assetization' (Birch et al. 2021) of corporate data relies on the aggregation of large amounts of data, government data also benefit from being interlinked. A digital rights activist put it like this: 'It is clear that we are heading towards a world where we'd like to make evidence-based statements about society on the basis of aggregated data. And it is one of the biggest tensions of our time, how to reconcile the protection of the individual and the benefits of large-scale data sets and aggregation.' Alluding to the economic value of government data, the policy maker responsible for Austria's data strategy said: 'Then, in the light of the European data strategy, or considerations about the creation of the Digital Single Market, economic rationales increasingly came to the fore.' Referring to far-fetched plans to build European Data Spaces, he added that companies would increasingly realise that 'hording data on its own' is no longer wise, but that 'market value lies in the sharing of data.' The value of data, however, significantly grows when data are interlinked, especially when stemming from different 'silos,' as he put it. Accordingly, the aggregation of administrative data requires a high degree of protection in Austria.

Talking about the Austrian Micro Data Center, the digital rights activist explained the controversy that sparked around its introduction. The aggregation of citizen data from different sectors was considered a delicate endeavour that would need to follow strict safeguards since it sets aside one of the central principles of Austrian data protection: the strict segregation of citizen data into different 'silos' to prevent the state from gaining an 'overall picture' of the life of citizens. What constitutes strict safeguards was discussed in different ways, however. While the digital rights activist argued that more measures should have been taken to protect citizens, the representative of the AMDC explained that they followed strict procedures oriented towards data minimisation and 'control work' to avoid risks of re-identification (Fuchs et al. 2023). She said the AMDC is aware that giving out one or two more individual variables to researchers could be enough to re-identify people, or institutions, even though each data set was properly pseudonymised. They thus assess with care each project proposal, the data sets required,

and the scientific output that is created on the basis of micro data—creating a huge bureaucratic process and requiring a whole range of new data work, skills, and resources.

Furthermore, commercial interests are at stake considering the high value of micro data. The issue centres around the question of accreditation and what constitutes a research institution in the first place—for example, pharmaceutical companies do research too, but are excluded from access to micro data at present. All these examples show the differing ways that the aggregation of administrative data has been discussed and how it involves essential and sometimes competing values. To master such balancing acts in the public interest, collaboration has been demanded by my interviewees.

Call for Collaboration

The call for collaboration was expressed as a response to the deep concerns involved in data sharing that were described as being rooted in Austria's culture of secrecy. Talking about the organisational implementation of the data strategy, the policy maker framed the Austrian situation as follows: 'So far, the Austrian viewpoint was strongly characterised by the aspect of voluntary intent. Because we had the professional secrecy, duty of confidentiality, and so forth, not much was possible.' Similarly, the representative of the data.gv.at platform referred to the culture of 'professional secrecy' when talking about the early days of the platform: 'Well, the idea of openness was not in our DNA at all, right?' An open data activist labelled the Austrian data culture as an 'imperial and royal [kaiserlich und königlich] culture of administration', a reference to the highly stratified and bureaucratic culture of the former monarchy. This comment corresponds to what Parycek and Schossböck (2015) framed as a 'longstanding culture of closure, state sovereignty, and the attributes of the Habsburg bureaucracy.'

Moreover, my interviewees described a deep anxiety among public institutions that mistakes, misconduct, or other misbehaviour would come out if they opened up and allowed people to peek into their inner workings. Talking about the elevator app for disabled citizens, the open data activist said that Viennese public transport was initially against sharing its real-time data since they were afraid that 'the political

counterpart' would use it as 'ammunition' to damage them if the app showed that many elevators did not work. Only when it turned out that the opposite was the case—that the elevators worked comparably well in Austria—did Viennese public transport see the gain of sharing their data. The Open Commons Linz representative summarised these deep anxieties like this: 'Will the shitstorm hit us? Those are the fears.' A potential loss of 'sovereignty' over political decision-making was additionally mentioned as a perceived obstacle to opening up government data—the flipside of transparency.

Talking about the building of complex, distributed data infrastructures, a city employee working on the digital geoTwin expressed a strong desire for collaboration—both on the technical and the organisational side. In addition to communication between public bodies, responsibility for data was raised as a critical issue. While the responsibility for single data sets would stay with the respective departments, the city employee said, the responsibility for data integration—and the added value it creates—was up for debate. Another interviewee involved in the digital geoTwin referred to the coordination work that would be needed to build such a distributed data infrastructure as crucial and concluded by saying: 'It is a topic where everyone needs to collaborate. It is a topic of communication and organisation. And we cannot pass it on to one individual.' This illustrates that public infrastructures, just like research infrastructures, need to be negotiated among different actors, backgrounds, and across sites (Star 1999; Karasti et al. 2010). Sometimes this negotiation can have high political stakes. If a digital twin visually displays detailed information about tunnels, water pipes, or the Viennese underground, it could become a matter of national security if such information is (mis)used for a terrorist attack. As the city employee concluded, 'Well, sometimes there is a conflict of interest between transparency and security.' To balance such delicate conflicts of interest, collaboration and stakeholder-engagement were suggested by my interview partners.

Contrary to government employees, who were reluctant to share data, the digital rights activist emphasised the positive effects collaboration could create: 'I think that public institutions would benefit from each other if they were more transparent, if they would know what others do. Because you don't have to invent everything on your own, you can

learn from each other.' The cultural shift that would be required for this to happen, according to the policy maker, includes a 'fundamental rethinking in the public sector altogether, that you don't think about yourself, your own data silo, but rather: 'How can I make my data useful for someone else?' In the next and final section, I will address the question of how to foster more collaborative ways of opening up data, building infrastructures, and governing datafication in public sectors.

Conclusions

In this chapter, I have discussed practices and politics of opening up government data in the Austrian context by focusing on three government data infrastructures: the open government data portal data.gv.at, the Austrian Micro Data Center, and the digital twin infrastructure of the city of Vienna. I have traced what a shift from professional secrecy towards a more open 'data culture' entails in practice, as the policy maker put it at Café Prückel. But what can we learn from Austrian attempts at infrastructuring openness in light of recent EU data policies and wider transformations of the 'data welfare state' (Dencik and Kaun 2020; Dencik 2022; Kaun and Masso 2025)?

Datafication of public administration, among other sectors, has become a central component of the European Data Strategy. Recent EU policy documents such as the Open Data Directive, the Data Governance Act, or the Data Act aim for a 'data-driven society' where data will 'flow freely within the EU and across sectors.'[8] European Data Spaces are imagined in areas like health or finance, where sensitive data are supposed to be shared between different stakeholders, countries, and contexts (EU REG 2022). While data is expected to 'flow freely' in EU policy, my research has pointed to the multi-faceted practices of infrastructure building, data work, and the intermediaries that are needed to make data flow. This resonates with research that has deconstructed notions of data as a mere 'by-product' of organisational practices that could simply be 'harvested' (Jarke and Büchner 2024). Moreover, crucial tensions and ambivalences arise when implementing

8 See https://commission.europa.eu/strategy-and-policy/priorities-2019-2024/europe-fit-digital-age/european-data-strategy_en

EU data policies into national data cultures, institutional contexts, and bureaucratic routines.

Austrian bureaucracy has its roots in the Habsburg monarchy, inheriting a tradition with secrecy at its core rather than transparency. Historic experiences of national socialism further contributed to Austria's strong stance towards data protection, which is encoded in strict data protection policies and rules (Mager 2017). In this cultural context, calls for opening up sensitive personal data would need to be met with strict safeguards to protect citizens (and institutions) from surveillance and discrimination that may result from re-identification, according to digital rights experts. Kaun and Masso (2025: 28) speak of the 'openness paradox' to describe the tensions between the push for open government data and the imperative to safeguard data due to privacy concerns and other risks. Moreover, the benefits of opening up government data were seen to be balanced with economic rationales of ab/using data for profit maximisation. This relates to broader tensions running through EU technology politics, which is torn between Normative Power Europe and Market Power Europe (Ulnicane 2021). It further relates to strategic uses of open government data to foster neoliberal principles such as the privatisation of public assets or the marketisation of public services (Bates 2014), if we consider larger trends in the data welfare state (Dencik and Kaun 2020; Dencik 2022; Kaun and Masso 2025).

To master the complex balancing acts between the different actors, interests, and values at stake, my research participants have suggested participatory stakeholder processes. Collaborative efforts and transdisciplinary expertise may help to sensitively implement Austria's data strategy in organisational practices and find ways to carefully govern data in distributed infrastructures. This could facilitate mutual learning across contexts, but also across countries, while still considering local specificities and 'situated ethics' (Mager et al. 2025). Nordic countries, for example, have been framed as transparent and 'information friendly' in the past (Parycek and Schossböck 2015), but have experienced severe scandals emerging from datafication and automation in public sectors more recently. Just think of the Dutch childcare benefits scandal, where the risk scoring algorithm used to detect welfare fraud showed serious effects of algorithmic bias and discrimination. Amnesty International labelled the software a 'xenophobic machine' because it particularly

discriminated against migrant families and other socially vulnerable groups (Amnesty International 2021). Despite this criticism, a similar fraud detection algorithm has been introduced in Denmark just recently and showed similar effects of 'coded injustice' (Amnesty International 2024), confirming research on algorithmic discrimination of (semi)-automated decision-making tools in public administration (Dubois et al. 2018; Allhutter et al. 2021). Sharing and broadening experiences and expertise would help stakeholders to collectively learn from devastating examples and prevent harm before risk scoring algorithms and other profiling techniques are introduced into public sectors (as an alternative to ex-post auditing and court rulings). Inspiration for transdisciplinary collaborations may be drawn from Schäfer et al.'s (2024) recent book, *Collaborative Research in the Datafied Society*.

Moreover, new concepts for thinking and governing data could make it possible to meet challenges posed by the increasing aggregation of government data. Prainsack et al. (2022) suggest a solidarity-based data governance framework that builds on three pillars: 1) facilitating data use that creates significant public value, 2) harm prevention and harm mitigation, and 3) sharing the profits of corporate data use with the public—the latter reflecting the open data activist's suggestion to pressure e-scooter companies to share their valuable city data. In this concept, the notion of public value is central,[9] arguing that the most important distinction is to be made 'between data use that generates significant public value without posing unacceptable risks to anyone and data use that does the opposite' (Prainsack et al. 2022: 7). The concept of data solidarity may thus serve as a guiding principle for opening up government data in the public interest. It may help to strengthen initial ideas built into open government strategies that are increasingly under threat in EU data policies that use the notion of open data as an act of 'window dressing' while fostering the economic rationale of the data economy, as discussed earlier. Rather than undermining public sectors with neoliberal logics by way of datafication, public administration could start thinking about how to share and govern data in a more responsible way, compared to Big Tech companies with their strategies of 'assetization' (Birch et al. 2021). As the

9 See Prainsack and Kickbusch (2024) for a mission-oriented definition of public value and Twizeyimana and Andersson (2019) for notions of public value in the context of e-government.

digital rights activist concluded, '*now* we have the chance to lay down the tracks and define the foundational orientation that will shape our digital future in the long-term.'

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5. The Future of Urban Waste: From Closed Systems to Open Waste Data Infrastructure[1]

Celina Strzelecka

1. From Waste to Data: Infrastructuring Urban Refuse

This chapter opens with a close examination of Poland's Digital Urban Waste Tracking System (DUWTS), a smart waste management system deployed in a small Polish municipality.[2] Through this empirical case, I explore how digital infrastructures transform waste into data—and what political and social implications this transformation entails. This matters politically because digital waste systems do more than track refuse: they configure new relations of responsibility and control between residents, municipalities, and private platforms.

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2 In line with research ethics as outlined by the Ethics Committee of the Institute of Philosophy and Sociology of the Polish Academy of Sciences, the Code of Ethics for Sociologists of the Polish Sociological Association, and the Data Management Plan submitted to the National Science Centre (Poland), the author does not disclose the actual name of the analysed technology. Instead, a synonymous term is used to preserve the anonymity pledged to research participants.

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In a small Polish municipality, the journey of household waste begins not with disposal, but with labelling. Residents must affix a unique QR-coded sticker to each waste bag before depositing it in large, electronically controlled ground containers. These containers—installed in clusters known as 'hubs'—are equipped with digital scales, motion sensors, cameras, and QR readers. Upon arrival, residents scan the QR code linked to their household. The container verifies the code, opens the lid, and, once the bag is deposited, records its weight. The lid then closes automatically. This seemingly mundane gesture triggers a series of technical processes that transform physical waste into structured data.

Each interaction generates multiple data points: the time and location of the disposal, the type and weight of the waste, and the identity of the household (linked via the QR code). This information is transmitted via the Internet of Things (IoT) to a proprietary cloud-based system operated by a private company contracted by the municipality. The data are compiled into individual digital profiles—quantitative representations of each household's waste behaviour—which are accessible to municipal administrators through dedicated dashboards, and to residents via a mobile app.

The system operates in three distinct phases. First, data is generated: residents interact with the smart infrastructure, producing timestamped waste records. Second, data is centralised and analysed: proprietary servers process inputs to generate statistical summaries, trend projections, and visual indicators of compliance or anomaly. Third, data is visualised and fed back: user-facing apps simulate pay-as-you-throw billing, display comparative rankings, and encourage behavioural adjustment. Throughout, access to raw data remains tightly controlled by the technology provider, despite official claims that it 'belongs to the municipality' (Interview with technology company employee, June 2023).

Yet this data infrastructure does not operate independently of municipal workers. Municipal employees remain essential to its operation, particularly when residents fail to comply—forgetting to scan codes, placing noncompliant bags outside containers, or mis-sorting waste. In such cases, staff must open containers, inspect contents, identify

offenders, and document infractions. Despite promises of automation, their work is often physically demanding. As one municipal worker remarked while inspecting waste in a DUWTS container: 'They told us that working in the municipal office would be office work, not digging through garbage' (Field notes, July 2024).

What unfolds here is a technologically mediated choreography of waste governance: a system that performs automation while relying on manual labour; that simulates fairness while obscuring systemic inequities; that collects data ostensibly for the public good while creating a form of proprietary lock-in. This chapter traces how waste becomes data—who produces it, who owns it, and who governs its flow—showing how systems like DUWTS, often labelled as *smart waste systems*, redistribute control and accountability in ways that challenge existing norms of public governance. The central argument is that while DUWTS promises greater efficiency and behavioural fairness, it in fact deepens municipal dependence on proprietary platforms and shifts systemic responsibility onto individual residents.

This chapter thus examines not only the mechanics of waste tracking, but also the broader political and infrastructural implications of smart waste systems. While the DUWTS system already exposes some waste data to residents—through personalised rankings, price simulations, and behavioural nudges—this form of selective 'openness' primarily governs individuals rather than enabling collective accountability.

Should waste data be open—and if so, under what conditions, for whom, and to what ends? As scholars of open data have argued (Tkacz 2012; Heimstädt 2017), transparency is not a neutral design principle but a contested political project—one that requires scrutiny, not celebration. Through the case of Poland's Digital Urban Waste Tracking System (DUWTS), I interrogate the tension between what might be conceived as digital efficiency and infrastructural closure. This means examining who defines what counts as openness, who benefits from it, and under what conditions it actually supports public accountability.

The entire infrastructure is developed and operated by a single private company, contracted by the municipality through a competitive procurement process. The contract, signed in 2022 and valued at approximately five million PLN, binds the municipality to a multi-year service agreement that includes system installation, server

maintenance, software updates, and technical support. Although the municipality formally owns the data, it lacks direct access to the servers or the capacity to audit or reconfigure the system independently (Field notes; interviews with municipal officials; system demonstration, July 2024). Any changes to data access, functionality, or visualisation must be negotiated with the company. Municipal officials described this arrangement as a 'vendor lock-in,' noting that the costs and complexity of switching providers would be prohibitively high. As one official noted, reflecting on the municipality's limited autonomy despite formal data ownership: 'We have the data, but only in name—the company decides what we can actually see' (Interview with municipal official, July 2024). This dependency reveals how public waste governance is increasingly shaped by proprietary infrastructures that remain opaque to those tasked with oversight.

2. From Personalised Waste to Simulated Pricing: The Making of Individual Responsibility

A key feature of DUWTS is its interface for residents—a mobile application that visualises personal waste data and simulates hypothetical billing scenarios. This personalised interface marks a significant shift in the governance of waste, moving from collective service provision to individualised monitoring and imagined pricing. The DUWTS mobile app's hypothetical pricing display shows users what they would pay under a hypothetical Pay-As-You-Throw (PAYT) model with weight-based charges (see Figure 5.1).

Upon opening the app, residents can view the amount and type of waste they have disposed of, the frequency of their waste drops, and their individual statistics compared to other households within the same estate, municipality, and even across Poland. One municipal employee explained:

> The user, meaning the resident, can see their data in the system: how much, when, and what kind of waste they've disposed of. [...] They can also compare their statistics, for example, with others—how they segregate waste according to their flat, block, estate, and municipality. [...] They can even see their ranking in Poland compared to other residents. (Interview with municipal employee, July 2024)

Fig. 5.1 Example of the DUWTS mobile app's hypothetical billing screen: simulated PAYT fee calculated per household waste weight. Source: public demonstration material. The exact view of the 'My Fees' tab has not been publicly released and is not accessible to anyone who is not a registered resident; therefore, it cannot be shared here due to research ethics considerations.

Although the application currently displays fixed municipal fees, it also presents fictional calculations of what residents would pay under a Pay-As-You-Throw (PAYT) model, where charges are based on the actual weight of their waste. The displayed prices are typically lower than the real fees, causing confusion and repeated complaints. As one municipal officer noted:

> The application misleads residents because it shows lower amounts than what they actually pay. We explain that it's just a demonstrative function,

> but the problem persists. [...] Residents would come and say they want to pay the amount shown in the application because it's lower. (Interview with municipal officer, July 2024)

Despite municipal concerns, the company has retained the speculative pricing feature. According to the provider, the PAYT system is 'ready for future implementation.' 'If the law in the future allows charging residents based on waste weight, our solution is ready. [...] The weight in the devices is certified, and this forms the basis for billing.' (Interview with technology company employee, June 2023).

The visualisation of hypothetical prices enacts a logic of fairness tied to individualised waste production. Company narratives frame the feature as educational, designed to raise awareness: 'It's a form of education because, as consumers and residents, we often don't realise how much waste we produce.' (Interview with technology company employee, June 2023).

But the implications of this feature go beyond education. The simulated pricing system subtly reshapes waste into a matter of individual responsibility, displacing systemic or collective accountability. This app does not simply present information; it produces a moral and financial framework that recasts waste as a calculable, personal burden.

Residents, confronted with ranked comparisons and performed financial consequences, are nudged to internalise the idea that their waste habits should be individually optimised. Similar forms of individualised waste governance also exist in other contexts, such as smart PAYT schemes implemented in parts of France (Le Bozec 2008), Sweden (Dahlén and Lagerkvist 2010), the Netherlands (Dijkgraaf and Gradus 2004), or South Korea (Park 2018), where household-level monitoring and pricing are used to incentivise behavioural change. These systems also deploy visualisations, rankings, or personalised feedback to encourage residents to optimise their waste habits. As Hobson (2002) and Shove (2010) argue, such framing reinforces neoliberal environmentalism, where systemic failures (e.g., lack of Extended Producer Responsibility) are rendered invisible, and behavioural change is offloaded onto individuals.

The DUWTS app thus functions not only as a technological monitoring tool but as a mechanism of responsibilisation. Its user

interface visualises a future framed as 'algorithmic fairness'—but this fairness is operationalised narrowly through household performance metrics set by the system's design, while broader questions of structural equity remain unaddressed. It implicitly promotes the belief that reducing one's personal waste output is an effective path toward sustainability, diverting attention from upstream waste production and policy gaps.

Moreover, by embedding individual pricing logic into an application still governed by flat-rate municipal fees, the app performs a governance model that does not yet exist in law. This anticipatory interface cultivates a readiness for personalised pricing while bypassing democratic deliberation or regulatory consent.

This pricing display, then, is not a neutral design feature—it is a speculative governance tool. It cultivates user habits and expectations, while presenting market-based individualism as both inevitable and desirable. In doing so, it transforms how residents perceive waste, responsibility, and their role within the urban metabolism. Taken together, these insights show how the DUWTS infrastructure not only monitors waste but also reconfigures accountability and everyday governance. This invites deeper questions about how infrastructure operates not just technically, but politically and ethically.

3. Analytical Reflections: Infrastructure, Responsibility, and the Politics of Data

The case of DUWTS illustrates how digital infrastructures do more than manage waste—they also reconfigure power, responsibility, and perception. In this section, I draw together key analytical insights from the preceding empirical discussion, engaging critically with debates from Infrastructure Studies, Critical Data Studies, and Discard Studies.

3.1 Governing through Infrastructure

To unpack these dynamics, I draw on Infrastructure Studies to show how seemingly technical systems embed social relations and power. Building on this, what appears as neutral hardware is deeply entangled with

everyday governance. Following Susan Leigh Star (1999), infrastructures are not neutral technical systems but socio-material arrangements that shape everyday life. DUWTS, as a waste data infrastructure, governs by making certain behaviours visible, traceable, and comparable. Its QR-coded containers, cloud systems, and mobile apps do not simply collect data; they organise social relations, creating new forms of accountability and dependency. The staged pricing model—though not legally binding—enacts a regime of governance based on behavioural metrics that quantify household waste output, sorting accuracy, and performance relative to neighbours.

This infrastructure also obscures certain realities: the work of municipal employees, the role of producers in generating packaging waste (which, while theoretically measurable, is not tracked at the source level in this system), and the systemic inequalities that shape access to waste services (e.g., differences in housing type or digital literacy). Infrastructures become visible when they break down or are contested, as evidenced by residents' confusion over pricing, or workers' resistance to the narrative of full automation. These moments of breakdown are not failures but revelations: they show how DUWTS enacts a specific vision of governance, one that privileges technological oversight over democratic deliberation.

The performative promise of automation—embedded in recruitment narratives that framed this as 'office work' (Field notes, July 2024)—conceals the material realities of labour required to sustain it. Workers are frequently called upon to intervene when containers fail to recognise QR codes, when residents leave untagged bags outside, or when mechanical parts jam. 'They told us it would be office work,' one employee laughed. 'They lied.' (Field notes, July 2024). The physical effort is not only repetitive but often unpleasant. 'It smells like fish,' another explained (Field notes, July 2024). 'Sometimes we spray the containers with Wunderbaum air fresheners just to survive the shift.' (Field notes, July 2024). Such accounts highlight the bodily cost of maintaining an ostensibly seamless system, revealing how smart waste infrastructures rely on hidden forms of care and correction (cf. Jackson 2014; Vinsel and Russell 2020). Rather than eliminating labour, DUWTS redistributes it—recasting workers as silent enforcers of automated governance while

rendering their contribution invisible in official narratives of efficiency. These tensions prompt a broader question: what alternatives might exist beyond narrow models of efficiency—and how might infrastructures communicate responsibility through the very metrics and visualisations they deploy?

3.2 Data as Moral Infrastructure

The DUWTS app exemplifies what Desrosières (1998) and Liboiron (2013) describe as the moralisation of metrics. Data is not only technical—it carries implicit norms about what counts, what matters, and who is responsible. The ranking systems and comparative visualisations embedded in the app construct waste not just as a material flow, but as a personal achievement or failure, quantified through household scores, weight-based statistics, and performance rankings. This produces a moral economy of waste in which responsibility is individualised and made visible through data.

Visualisation plays a central role in this moral economy. The DUWTS app does not simply convey raw metrics—it renders waste into interpretive artefacts. Graphs, comparative bars, colour-coded alerts, and simulated price breakdowns are all designed to generate emotional responses and encourage self-discipline (see Figure 5.2 for an illustrative example of how these visualisations appear in practice). Following Tufte's (1983) insight that data graphics encode specific narratives, and Desrosières' (1998) claim that statistics both describe and prescribe social order, these visualisations not only inform but also instruct. They guide users toward particular interpretations of fairness and proper behaviour. As discussed in the contributions collected in Moser and Dilling (2007), visualisation operates as a powerful tool in environmental governance—not merely by simplifying reality, but by framing problems so that particular solutions appear natural or inevitable. In DUWTS, this means that reducing personal waste, as visualised through clean graphs and downward-pointing arrows, becomes not only a personal virtue but an unquestioned environmental imperative.

Fig. 5.2 Example of comparative performance bars and visualised waste statistics in the DUWTS app (real promotional screenshots based on publicly available demonstration material).

This responsibilisation process echoes critiques from Critical Data Studies. As Iliadis and Russo (2016) argue, data practices often serve to reinforce existing hierarchies and shift burdens onto already marginalised actors. DUWTS promotes a vision of environmental justice that is measurable, personalised, and apolitical—thus sidestepping questions of systemic accountability. Yet this openness is one-sided: it governs individuals while leaving systemic data flows opaque.

3.3 Wasting Well: Challenging Technosolutionism

Building on the tensions identified above, this section connects the empirical contradictions between individualised data and systemic invisibility to broader debates in Discard Studies and environmental justice. Liboiron and Lepawsky's (2022) notion of 'wasting well' calls for a shift from efficiency-focused solutions to socially just approaches that account for the political economy of waste. The DUWTS system, while technologically sophisticated, fails to address root causes such as overproduction, the lack of strong policies holding producers accountable for packaging waste, and public disempowerment. Instead, it repositions users as both data producers and targets of behavioural governance.

To 'waste well' would mean designing infrastructures that redistribute—not concentrate—responsibility and agency. This would require transparency about data control, equitable participation in design, and a reorientation away from punitive simulations of fairness toward collective strategies for reducing waste. The current model of DUWTS performs a narrow solutionism: it answers questions of traceability—understood here as monitoring and control—while avoiding questions of justice.

A closer application of 'wasting well' to the DUWTS case reveals the contradictions between technological promise and infrastructural justice. While DUWTS claims to promote sustainability through efficiency and traceability, it obscures systemic contributors to waste production and reinforces hierarchies in data access and decision-making. Liboiron (2013) emphasises that dominant waste systems often shift environmental and economic burdens onto municipalities and residents, especially under conditions of weak Extended Producer Responsibility (EPR). In DUWTS, data is generated by residents but controlled by private entities; accountability is individualised onto residents, yet packaging producers remain invisible. This asymmetry runs counter to the principles of 'wasting well,' which call for participatory data governance, transparency, and redistributive accountability. Instead of reinforcing consumer responsibilisation and opaque data ownership, waste infrastructures should be designed to foster equitable partnerships between residents, municipalities, and

producers—ensuring that responsibility is not only traceable but justly assigned. The implications of such speculative design deserve closer scrutiny, especially in how they shape governance futures.

3.4 Infrastructure as Future-Making

Finally, DUWTS is not only an instrument of present governance; it is also a speculative infrastructure. This builds on the previous sections by asking how infrastructures project futures before they are debated. By simulating pricing models and anticipating regulatory shifts, it prefigures a future that may never be publicly debated. As Mager and Katzenbach (2021) argue, infrastructures shape future imaginaries: they embed assumptions about what should be, not just what is. The predictive logic of DUWTS—its anticipatory visualisations, automated alerts, and readiness for PAYT billing—contributes to a future where surveillance and personalised pricing are seen as inevitable.

As Star (1999) and Edwards (2010) remind us, infrastructures make some aspects of the world visible, knowable, and actionable, while rendering others invisible. Waste data systems like DUWTS structure not only information flows but also perceptions of responsibility and efficiency. They reinforce a framing of waste as a technical problem solvable through automation, while obscuring persistent needs for manual labour and the role of producers. As Stamatopoulou-Robbins (2019) notes, infrastructures often redistribute burdens rather than eliminate them. In DUWTS, this does not mean an equitable redistribution: instead, it concentrates governance power in private hands while shifting accountability and labour burdens onto residents, leaving structural contributors to waste unaccountable.

A critical evaluation of infrastructures like DUWTS requires us to move beyond questions of technical function and efficiency. These systems actively shape governance futures by embedding particular social and economic assumptions—about who should act, who should pay, and who gets to know, including intimate details about residents' everyday lives revealed through their waste. As speculative infrastructures, they configure not only what waste is, but what it should become. To hold such systems accountable, we must politicise their futures: challenging the technocratic logics they normalise, and foregrounding democratic

deliberation, equity, and infrastructural care as essential components of any data-driven transformation.

4. From Speculation to Implementation: Reframing Openness in Waste Data Infrastructures

Having seen how DUWTS performs selective openness, it becomes crucial to ask what a more democratic form of openness could look like. This requires distinguishing between openness as a normative ideal—linked to participation and accountability—and its strategic or contractual forms, which may reinforce control by private actors. Building on the idea that infrastructures configure futures, this section shifts focus to how the notion of 'openness' itself is prefigured and mobilised within DUWTS. While this chapter began by asking whether waste data should be open, this section critically unpacks what such transparency actually means in the context of digital waste infrastructures like DUWTS. Drawing on critical scholarship (Tkacz 2012; Heimstädt 2017; Dobusch et al. 2019), I argue that openness is not a neutral design principle but a politically contested and socially embedded concept. Rather than treating data openness as an inherent good, we must ask who defines what counts as transparency, who benefits from it, and when it serves public accountability.

DUWTS presents itself as a system ready for data transparency and behavioural optimisation. Its dashboards and app interfaces simulate a personalised openness through data visualisations and comparative rankings. However, the underlying data infrastructure remains closed: proprietary servers process information beyond public oversight; raw data is inaccessible to municipal actors without the intervention of the technology provider, which is not in the contract; and long-term contracts entrench infrastructural dependency. Although municipalities are nominal data owners, they lack technical autonomy. This limitation was echoed in interviews with municipal officials. As one municipal official explained: 'If we wanted to implement anything on our own—we couldn't. Every change has to go through the company. We are accountable to the residents, but they [the company] hold all the codes.' (Interview with municipal official, July 2024).

This creates a paradox: data is produced by residents, governed

by private actors, and mediated to users through selectively designed interfaces that privilege the provider's vision of efficiency and fairness.

Smart city initiatives such as the Integrator Danych Miejskich (Urban Data Integrator—the first research and advisory programme in Poland focused on urban data governance) often call for public municipal waste data, including waste streams (Instytut Rozwoju Miast i Regionów). For example, cities like Gdynia already publish aggregated waste collection statistics on their public data portals (Miasto Gdynia). But such selective transparency must be treated with caution. As Heimstädt (2017) warns, openness without structural change risks 'open-washing'—the performance of transparency without real accountability. If granular waste data were made public, it could reinforce socio-spatial inequalities, stigmatise neighbourhoods, or be appropriated by commercial platforms. Moreover, unrestricted disclosure without community consent and alignment with privacy laws undermines the principles of data justice and democratic participation.

Instead of advocating openness as a default, I propose reimagining it as a governance practice. This involves designing infrastructures that support pluralistic data use, ensure public stewardship, and foreground the rights of data subjects. In the context of DUWTS, this would mean enabling municipalities to audit and repurpose data independently; establishing safeguards to prevent any future discriminatory uses; and creating participatory mechanisms for residents to shape data and waste policies. Only by embedding such transparency within democratic and redistributive frameworks can waste data infrastructures move from speculative control systems to tools for public good.

5. Methodological Reflections: Ethnography of Infrastructure and Anticipatory Anthropology

This chapter draws on a multi-sited ethnographic study conducted between 2023 and 2024 in a Polish municipality that piloted the DUWTS system. The research involved twenty-five in-depth interviews with municipal officials, technology company employees, waste management contractors, and residents; participant observations during training sessions and public meetings; and document analysis of regulatory frameworks, procurement contracts, and company presentations.

Additional material came from direct interaction with the mobile app, access to anonymised user data screenshots, and an extended visit to the system operator's headquarters.

5.1 Ethnography of Infrastructure

Inspired by the work of Susan Leigh Star (1999), Brian Larkin (2013), and Ribes and Lee (2010), this study treats infrastructure not as technical background but as a political artefact—rendered visible through empirical attention. Rather than studying waste solely as an environmental or logistical concern, I approached DUWTS as an infrastructure of governance: a material-semiotic assemblage that structures visibility, action, and power. This study adopts an infrastructure ethnography framework to trace how waste is transformed and made actionable through digital systems. Interviews with municipal workers, for example, revealed how the system's promise of automation depends on ongoing human oversight. Observations of app interactions showed how data representations shape residents' sense of fairness and responsibility.

5.2 Multi-perspectival Approach

The study was deliberately multi-perspectival. I treated municipal actors not merely as implementers, but as negotiators of competing temporalities—caught between the long-term contracts with private providers and the short political cycles of local governance. Technology company representatives were approached as infrastructural designers whose visions of efficiency and education are inscribed into algorithms, interfaces, and anticipatory features. Residents were not seen as passive recipients but as active interpreters—sometimes enthusiastic, sometimes resistant—of the meanings assigned to their data. This approach allowed me to trace not only the official narratives but also the frictions, breakdowns, and informal adaptations that emerged around DUWTS.

5.3 Anticipatory Anthropology

A central conceptual thread in this research is the idea of anticipatory anthropology (Miyazaki 2003; Adams, Murphy, and Clarke 2009).

DUWTS is not simply a tool for managing current waste flows—it is also a speculative infrastructure that prefigures a future of individualised billing, predictive enforcement, and automated governance. As such, I treated future-oriented artefacts—such as simulated pricing in the app and dashboards showing 'what would happen if...' scenarios—as ethnographic material in their own right. By attending to how infrastructures imagine and enact futures, I aimed to understand how technical systems mobilise behavioural change, legitimise certain governance models, and marginalise alternative ones before they enter public debate.

This methodological orientation made it possible to investigate not only how waste becomes data, but also how that data becomes politically potent—how it structures governance in the present while projecting a particular vision of what governance should become. This lens foregrounds the politics embedded in infrastructural design and allows us to interrogate not just what waste data does, but what it is made to do.

6. Beyond Open-washing: Designing for Data Justice in Waste Infrastructures

If the DUWTS system is framed as being ready for future openness, what kind of openness should that be—and for whom? The notion that open data is inherently good has long been problematised (Tkacz 2012; Bates 2014). Transparency alone does not guarantee accountability, and nominally open infrastructures can easily serve technocratic, extractive, or disciplinary ends if their design is not democratised. In this section, I argue for rethinking openness as a relational, negotiated, and situated practice grounded in principles of data justice.

Infrastructures that govern waste data should begin not with universal access, but with meaningful participation. This involves not only making data technically accessible, but co-defining what kinds of data are collected, how they are used, and by whom. In the context of DUWTS, such an approach would require establishing mechanisms through which residents, municipal workers, and civil society actors can shape data policies—deciding, for instance, whether and how individual metrics should be visualised, or which indicators should be

used to monitor collective waste trends. Without such input, the system risks reinforcing pre-defined narratives of individual fault and technical optimisation.

Alternative models already exist. The concept of data commons (Beckwith et al. 2019) suggests that datasets can be collectively governed as shared resources, with embedded protocols for consent, accountability, and redistribution. In a 'wasting well' infrastructure, data could be used to track not only household performance but also producer responsibility: mapping packaging waste to corporate sources, supporting citizen-led audits, or informing public procurement. This would shift the analytic focus from bottom-up responsibilisation to systemic accountability.

In contrast to this centralised, privately governed architecture, some municipalities in Poland have pursued more grounded and participatory forms of infrastructural experimentation. Several have established decentralised mini-PSZOKs (selective municipal waste collection points), managed by local cooperatives or neighbourhood councils. These small-scale sites allow residents to bring problematic waste—such as electronics, batteries, or bulky items—closer to home, improving both convenience and sorting quality. As one local coordinator explained: 'One of our municipalities explored this solution, and it turned out to be the most effective model among those analysed. These points are close to residential areas and staffed by people who sort the waste manually—this produces higher-quality materials for recyclers.' (Interview with local coordinator, independent waste expert, January 2024).

In some cases, the operation of mini-PSZOKs has also created jobs for local residents and fostered stronger ties between municipal services and the communities they serve. These practices show that waste infrastructures can be designed around values of accessibility, relational care, and shared responsibility, rather than optimisation alone. Recognising and supporting such grassroots innovations is essential for imagining data governance frameworks that emerge from existing ecological and social commitments—not just digital abstraction.

Such a model would also prioritise infrastructural care. Following calls for 'just data' (Dencik et al. 2019; Draude 2022), a participatory waste data infrastructure would recognise the social relations and power asymmetries embedded in digital systems. It would involve municipal

sovereignty over data servers, fair contracts with technology providers, protections against discriminatory use of data, and mechanisms for regular auditing. Transparency here emerges as a collective capacity: the ability to question, intervene in, and reshape how waste and its data are governed.

Avoiding 'open-washing' requires more than publishing datasets or displaying dashboards. It requires a shift in infrastructural politics—from platforms that simulate openness to systems that redistribute control. Rather than expanding what is visible, the goal must be to expand who can act. This reorientation—from access to agency, from metrics to meaning—offers a pathway toward more democratic, sustainable, and socially attuned waste data futures.

7. Conclusion: From Datafication to Democratic Waste Futures

The case of DUWTS reveals how digital infrastructures are not just tools of measurement and management, but active agents in reconfiguring responsibility, control, and the political imagination of waste. From the moment a QR code is scanned on a rubbish bag, through the production of digital profiles and speculative pricing displays, the system embeds a logic of behavioural governance rooted in personalised responsibility and infrastructural opacity—most visibly enacted through the app's comparative rankings and speculative pricing displays.

Rather than delivering on its promise of efficiency and fairness, DUWTS produces new dependencies—municipalities bound by long-term contracts, residents nudged by speculative metrics, and workers caught between manual intervention and digital automation. Its datafication model privileges traceability over accountability and reduces complex social processes to measurable inputs. The system anticipates a future of automated waste regulation, but in doing so, bypasses public deliberation on what forms of governance are desirable or just.

This chapter has argued for reframing waste data not as a neutral by-product of smart systems, but as a contested political terrain. Through the lens of 'wasting well,' I have shown how current data regimes individualise responsibility while obscuring structural contributors to waste. Through a critical engagement with openness, I have proposed

that transparency must be embedded in governance practices, not simply interface features. And through anticipatory anthropology, I have demonstrated how digital infrastructures actively shape expectations of the future, making certain trajectories appear inevitable.

If we are to imagine alternative waste futures, we must politicise the infrastructure of data itself: demanding participatory design, municipal autonomy, and equitable redistribution of responsibility across actors—including producers, platforms, and policy makers. Only then can the promise of data be reclaimed—not as a tool of optimisation, but as a shared capacity for reimagining the terms of environmental justice.

What this case reveals is not only a specific configuration of waste data governance in one Polish municipality, but also a broader pattern relevant across Europe: the creeping normalisation of opaque, privatised digital infrastructures in public service domains. As cities seek to modernise waste systems in the name of efficiency and sustainability, critical questions must be asked about who controls the data, who benefits from its use, and how democratic oversight can be maintained. The future of urban waste depends on confronting these infrastructural politics directly. As shown by local experiments like mini-PSZOKs, more democratic and participatory forms of waste infrastructure are already emerging, pointing to futures built on shared responsibility and transparency rather than proprietary control.

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6. The Politics of Federated Protocols: Openness Organised through Digital Sovereignty

Francesca Musiani[1]

'Sovereignty necessarily means decentralisation': with this seemingly paradoxical statement, D., a Belgian technology entrepreneur, began the 'Messaging for Government' workshop held on 31 January 2025 in Brussels as part of FOSDEM, the international conference of open-source software developers. This workshop brought together around thirty people, mostly developers involved in the Matrix federated communication protocol project, but also entrepreneurs and researchers. The workshop focused on an ambitious project: offering European governments a secure and decentralised messaging system. The debate was lively, and unanimity was not easy to achieve regarding the choice of protocol to adopt, the features to implement, and the strategies to choose for proposing this type of project to governments. But one conclusion was shared by the entire room: the future official messaging system for European Union governments would need to be 'federated' and 'interoperable.'[2]

This observation may surprise longtime observers of decentralised networks, like my colleague Ksenia Ermoshina and I. Why is decentralisation, often associated with 'alternative internets' (Dulong

1 This chapter draws on work carried out with Ksenia Ermoshina as part of the DIGISOV project: https://digisov.org

2 See further https://archive.fosdem.org/2025/schedule/track/government-collaboration/

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de Rosnay and Musiani 2017), and so highly valued by communities identified as 'resistant' or even subversive, such as hackers and cypherpunks, now considered fundamental to European technological sovereignty? While interest in federated architectures has been growing steadily since the late 2010s, it now seems to be moving beyond the circles of techno-enthusiasts and invading the public sphere. In the context of the profound techno-political upheavals brought about by Donald Trump's second term as US president, the issue of hosting digital communication services in European territories is beginning to take on unprecedented importance in discussions among experts and policy makers. My current research with Ksenia aims to understand how federated solutions are being mobilised in the context of debates on European digital sovereignty and self-determination.

Federated or decentralised social networks and messaging services are often perceived by the general public (and even analysed by some specialists) as technological utopias used by audiences with very specific characteristics, relatively marginal, and few in number. However, the Fediverse is currently experiencing a surge in popularity (La Cava et al. 2021; Rozenshtein 2023) that coincides with the development of digital sovereignty strategies on the part of many European states, and European institutions themselves (Roberts et al. 2021). Indeed, faced with the dominance of US-hosted services (such as WhatsApp or Signal) in the secure messaging market, Europe is seeking to deploy alternatives. Our research aims to explore how the various technical properties of federated solutions (such as interoperability, self-hosting, portability, modularity) are currently being invoked and mobilised by certain internet regulators in order to serve the objectives of digital and infrastructural autonomy. The more general question we seek to address concerns the controversy surrounding the reuse, or even co-optation, by different institutional and regulatory actors, of alternative tools and protocols developed by free software communities, often carrying libertarian and/or anti-authoritarian values.

As the label 'digital sovereignty' (see e.g., Couture and Toupin 2019; Pohle and Thiel 2020) is increasingly mobilised by practitioners and researchers of the internet and digital governance, a perspective based on science and technology studies (STS) and more specifically on infrastructure studies enables us to examine the co-development of the

material, institutional and territorial components of digital sovereignty (Easterling 2014; Amoore 2018; Möllers 2021). Approaches embedded in infrastructure studies allow us to show that 'digital sovereignty' is woven through situated and contextualised devices; they open the way to an understanding of the 'situated practices' embedded in the infrastructures of various political and economic projects that aim to establish autonomous digital infrastructures in a hyperconnected world. They also demonstrate the scalability and ontology of digital infrastructures as 'processes' rather than 'objects,' leading a body of recent work to speak of 'infrastructuring' (Blok et al. 2016; Karasti and Blomberg 2018; Musiani 2022 on the relation of this concept to digital sovereignty studies).

To shed light on how digital sovereignty strategies are embedded in infrastructures, and to understand what this reveals about the transformations of institutions and territories, two main 'gestures,' both theoretical and methodological, are desirable (see Musiani 2022). Firstly, to track the systems and arrangements, based on digital infrastructures, where sovereignty as a founding principle of the nation-state is promised, desired, constructed, and co-opted. Secondly, to focus on the technical components of digital infrastructures as strategic sites to trace the inscription of particular visions of sovereignty. This commentary adopts this theoretical and methodological position by analysing digital sovereignty as a set of social practices, intimately linked to the way humans and organisations build, develop, use, co-opt, and resist digital infrastructures.

The specificities of European digital and technological sovereignty are most often examined through the prism of political and legal science, notably by analysing the set of ambitious legislative initiatives that the EU has implemented in the last ten years, from the General Data Protection Regulation (GDPR) to the recent Artificial Intelligence Act, including the Digital Services Act and the Digital Markets Act (DSA/DMA). However, the infrastructural prism is useful for understanding how Europe is positioning itself in an increasingly interconnected world dominated by non-European technological actors. One tool for assessing Europe's dependence on foreign solutions is the Digital Dependency Index, which highlights the continent's strategic weaknesses in digital software and services. To reduce this dependence,

several initiatives have emerged, particularly in the area of sovereign messaging. Several European solutions, such as Tutanota, Olvid, or BundesMessenger, offer secure alternatives to foreign services while defending the use of open-source solutions. Interestingly, while the fairly classic arguments concerning transparency (and therefore the impossibility of an equipment manufacturer or digital service secretly reading or intercepting data) are put forward here as in the past, some of these services also mobilise economic arguments. BundesMessenger notes, for example, that 'while many solutions on the market have licenses based on the number of users, which means that costs are charged per user, BundesMessenger has an open-source license. The authorities only incur costs for operating their own backend.'[3]

Aware of its numerous digital dependencies at both the software and hardware levels, Europe is striving to build its own digital industry and strengthen its competitiveness by supporting innovation in semiconductors, artificial intelligence, and emerging technologies. The Open Source Observatory (OSOR) tracks and documents open-source initiatives across Europe, providing resources to administrations and businesses wishing to adopt sovereign solutions. Events such as FOSDEM and platforms such as Sovereign Tech facilitate networking among stakeholders engaged in this digital transition. Among these solutions for 'infrastructuring' European digital sovereignty—arguably the most prominent and controversial of the last five years has been the Gaia-X 'sovereign cloud' project (Adler-Nissen and Eggeling 2024)—digital services supported by federated technical architectures are gaining ground.

Federated Architectures

With the growing popularity of the Fediverse, primarily known for its flagship project, Mastodon, but also with the popularisation of the Matrix protocol and chat-over-email solutions like Delta Chat, federated solutions are currently experiencing a phase of increased development and use. As evidenced by the massive exodus of users from the 'X'

3 See https://archive.fosdem.org/2025/schedule/event/fosdem-2025-5572-opendesk-on-opencode-developing-a-secure-office-suite-and-sdlc/

platform to decentralised and interoperable alternatives, user trust in centralised platforms is in crisis. 'Federation' is increasingly seen as an alternative, on the one hand, to centralised applications that introduce a central point of vulnerability into the system, and on the other hand, to peer-to-peer (p2p) applications, which often require higher levels of commitment, expertise, and responsibility from the user (and their device). The Fediverse advocates' slogan, 'Protocols instead of platforms,' signals the promise of a major shift in the balance of technological, as well as political and social, power between the owners of major digital platforms and the administrators of decentralised local servers.

Federated architectures mobilise a new type of actor, sysadmins, responsible for maintaining the server cluster required for federated networks. By distributing the workload, federation is supposed to help mitigate the responsibility of a centralised service provider, while also distributing this responsibility and the 'computational resources'—that is, the hardware and logistical resources necessary for the network's proper functioning—with varying degrees of possible commitment, while promoting users' freedom to choose between different solutions and servers.

The secure messaging developer community is engaged in lively debates about the limitations and potential of decentralised protocols—debates that Ksenia Ermoshina and I documented online and during our field observations at professional conferences. Discussions about the tensions between centralisation and more distributed architectural forms, such as federation, go hand in hand with debates about standards. Proponents of federated solutions argue that reusing existing standardised protocols or developing new standards can improve interoperability and resolve the problem of 'messaging silos' (Kent 2019).

Federated projects promote interoperability as a solution to the 'walled gardens' of secure messaging applications. Building a system that is potentially open and modifiable according to the needs of a community also means taking some of the work away from the development team and delegating it to local entities. Indeed, federated architectures seem well suited to promoting localism and small, community-driven solutions, whose business model does not depend on the number of users and the availability of their data for collection and aggregation.

On the other hand, according to advocates of centralised solutions, federation can pose security challenges, as it is more difficult to audit all the different implementations of a federated protocol and ensure that all servers are properly configured. Indeed, federated messaging solutions add a layer of complexity to the governance of the socio-technical networks they structure, as they introduce the need for decentralised administration of servers (or 'instances').

Federation is understood as an infrastructural and social experiment, seeking a compromise between distributing responsibilities across a larger number of actors, high levels of security, and improved usability. In this sense, federation becomes a political and technical project that recognises the inherent dangers of centralised solutions, but offers an intermediate solution between centralisation and full-fledged distribution, as in the case of peer-to-peer tools, the latter of which are considered to require a steeper learning curve. Federation is also a means of making messaging applications censorship-resistant, a factor that plays an increasingly important role for users living in repressive contexts.

While the developers we interviewed for this study agree that decentralised systems are more difficult to design, their motivation to work on federated systems seems to be based on the political and technical aspects of federation, primarily the autonomy it can offer users by empowering them to control their own data and enabling better metadata protection. A developer of the ChatSecure application told us:

> I would like to allow people to manage their own infrastructure around their own data as much as possible. There are other great tools that provide encryption, like Signal, and you can, of course, use WhatsApp or Facebook Messenger, which use the same Signal protocol. But [in WhatsApp and Facebook Messenger] you still don't own your data; all metadata is controlled by a centralised system, which knows all your contacts, who you message, and at what time.

Another argument in favour of federated architectures, as opposed to centralised and purely peer-to-peer architectures, emphasises users' freedom to choose between different services, as the lead developer of Matrix explains:

> I had a long conflict with Moxie Marlinspike [Signal's head developer] about [decentralisation versus centralisation], mainly because Matrix

> is clearly an interoperable decentralised network, and he considers it a privacy risk because you can't control the entire network, there may be insecure implementations, there may be bugs that you can't control, which leak sensitive information, and it's a privacy issue. However, I would say that decentralisation is also important for the user's freedom and ability to choose which service they want to use.

The Politics of Federated Protocols

In this sense, federated protocols are often compared to political systems, where users can 'vote with their feet' by leaving one server in favour of another that better suits them. Federated protocols are supposed to enable greater accountability and control over service providers. Furthermore, the ease of migration offered by interoperable environments allows users to choose a better option without losing their social graphs. LEAP developer Elijah Sparrow told us: 'There's no way to establish any accountability for centralised services that lock people in. It's very easy, with federated services, to choose and leave a provider that does something you don't like. So, tomorrow, Signal starts doing something that people criticise, it will be very difficult to get people to leave Signal and use something else.'

The ability to develop a client based on an open federated protocol, with the features needed by a specific user community, was also highlighted as a positive aspect of federation, even if it limits the use of these solutions to a more technically savvy audience or requires localisation efforts.

Some developers and digital security trainers we interviewed over the years justify federation as reflecting the organisation of anti-authoritarian social movements, which echoes Nathan Schneider's (2019) conceptual analysis of the sociotechnical meanings of decentralisation. However, decentralisation is now beginning to be instrumentalised in discourses on European technological sovereignty. In this context, "decentralising" means shaping one's independence from foreign powers and their infrastructures.

However, our research shows that the adoption of federated solutions by public institutions is slowed by major contradictions inherent in the tools themselves, their functionalities, and the basic technological choices made by the protocol authors. Indeed, developers of decentralised

encrypted messaging solutions make their design and implementation choices by imagining certain user profiles for their tools, particularly by anticipating their threat models (Ermoshina and Musiani 2022). Projects such as Delta Chat, Riot (the former name of Element messaging), Conversations, Briar, Session, Quiet, SimpleX, and other encrypted and decentralised messaging services initially targeted activists, rights defenders, journalists, and other high-risk users. Having the ambition to offer maximum protected communication spaces, and being conditioned by very specific funding (such as DRL, Open Technology Fund, NED and other programs that emphasise 'technologies for social good'), these projects have invested considerable efforts in anonymity or at least pseudonymity, extreme protection of metadata, ephemeral messages, ease of migration and change of accounts, etc. While high-level encryption represents an asset for governments, and the open-source model represents an indisputable economic attractiveness, other features and dynamics specific to these usually 'alternative' devices, such as anonymisation, ephemeral messages, 'blind' servers and other advanced security parameters, on the contrary, become a set of constraints for states and institutions, because they conflict with the demands for archiving communications, their transparency, strong authentication and user verification.

How Digital Sovereignty Strategies Are Embedded in Infrastructures

Long considered by both specialists and practitioners as technological solutions that are both a decentralised utopian dream and a niche use case, federated solutions are now being used as leverage in the development of digital sovereignty strategies by many European states, as well as by European institutions themselves.

As Ksenia Ermoshina and I delve into the 'infrastructure-based' digital sovereignty strategies deployed by Europe and European states, and then into the role of federated systems within this strategy, we are looking in particular at the development of the Matrix protocol and its implementations in 'generic' messaging tools, such as Element, but also, increasingly, in projects designed by and for governments, such as (in France) Tchap. We examine, in particular, how the developers

and administrators of these platforms approach the issue of reuse of their services by state institutions, and what the implications of these shifts and reconfigurations are for the definition and implementation of digital sovereignty.

In a context of numerous digital dependencies, at both the software and hardware levels, European institutional digital technology is choosing to 'become an alternative internet.' The technical properties of federated architectures, marked by visions of interoperability and technological autonomy and governance, have long found an almost natural resonance with communities of activists, users with advanced technical skills, or niche needs. These same properties are now being reappropriated, mobilised, and 'made its own' by a public authority that wishes to free itself from the technological and economic barriers imposed by the quasi-monopolies of Big Tech. However, these efforts at adaptation and reconfiguration reveal or lead to a certain number of constraints that are also intrinsic to the federation's functionalities. For public stakeholders—and for developers of technical solutions adapted to the specific context of the public sector—it is a matter of imagining workarounds and compromises likely to institutionalise the 'alternative,' while avoiding compromising its founding model linked to encryption, open source, digital freedoms, and sometimes obfuscation.

By making these design and technological development choices, the digital sovereignty of Europe and European states is taking shape. Alongside the significant legislative arsenal that Europe has been putting in place over the past decade to position itself as a 'pioneering regulator' of the digital industry, European public sector stakeholders are pursuing digital sovereignty solutions forged 'through infrastructure,' by embedding specific visions of the digital Europe of tomorrow into architectures and technical infrastructures. Additionally to government ambitions, digital sovereignty projects are being spearheaded by organisations that are adopting federated solutions to deploy semi-autonomous zones, protected both from the surveillance of large corporations and from the influence of states in their efforts to control connectivity.

Given the evolution of digital geopolitics, particularly the growing politicisation of large American technology companies, the mobilisation and institutionalisation of 'alternative internets' to promote the self-

determination of communities and states is certainly only in its infancy—as is the research that will examine these phenomena in the future.

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III. INCLUSIVE GOVERNANCE OF DIGITAL KNOWLEDGE INFRASTRUCTURES

7. OpenEdition as a Governed Milieu: Towards an Ecological Understanding of Open Digital Knowledge Infrastructures

Simon Dumas Primbault

Introduction

Infrastructures are intrinsically dynamic. As the complex assemblage of heterogeneous stakeholders and socio-technical devices in 'trading zones' (Galison 1997), they are constantly deteriorated by centrifugal forces that pull apart their components: hardware wear, corruption of information, unresolved controversies, loss of relevance. Deteriorating infrastructures need constant maintenance work to continue to perform their functions.

Open digital knowledge infrastructures are dynamic in their specific ways. The irruption of digital networks at the turn of the twenty-first century opened the black boxes of long-standing and integrated knowledge infrastructures such as libraries or publishing houses and redistributed actors, skills, and responsibilities. New objects emerged—e.g., digital publications and data, information exchange protocols, dissemination platforms, online indexes, open licences—together with new expertise, norms, and vocabularies. This context redefines the dynamics of knowledge infrastructures, not only because they are ever more heterogeneous and fragile, but most importantly because the

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negotiation of what 'open' means raises other issues of transparency and participation, diversity and inclusivity, community and commons (UNESCO 2021).

A diverse array of stakeholders—including infrastructure practitioners,[1] researchers, and managers across various domains—increasingly use the term 'ecosystem' to refer, often loosely, to this emerging configuration of infrastructures, their communities, and their surrounding environments.[2] For example, a software ecosystem may refer to a set of interoperable building blocks connected through application programming interfaces (APIs). The book ecosystem, formerly book chain, alludes to the many steps and actors involved in the process of publication from editorial staff, to publishing standards such as ISBN, to circulation networks in digital and printed formats.

However, said stakeholders rarely take the step of explicitly defining the term 'ecosystem'. What does the rise of this vocabulary in the professional parlance of infrastructure practitioners reveal about shifting dynamics and the politics of open infrastructures? How do they engage with the ecological semantic field—if they engage with it at all? What representations and understandings do these professionals hold of their 'ecosystem,' and how do these perspectives influence their daily practices and the governance of infrastructures?

In this contribution, I would like first to document how scholars in infrastructure studies as well as in a broad range of disciplines use the term 'ecosystem.' Thanks to a brief literature review, we will see how it is discussed as a concept and serves to emphasise the need for a relational and scalar approach to socio-technical environments. Secondly, I would like to document how infrastructure practitioners use the term 'ecosystem' in the context of their work. Based on a survey and four interviews with agents of OpenEdition, I will show why they use this term or not, and how this helps them frame their professional experience. Thirdly, I aim to define the term 'ecosystem' as an analytical concept, emphasising the fragility of infrastructures, their specific dynamics, and

1 I call 'infrastructure practitioners' all actors—engineers, editors, administrators, and so on—that work from within infrastructures, on their development and maintenance. In the case of OpenEdition, drawing on institutional vocabulary, I call them agents.

2 See, for example, the number of documents indexed by GoTriple or Google Books mentioning the term 'research ecosystem.'

the resulting need for governance both within the infrastructure itself and at its interface with the surrounding environment.

The first section of this chapter will be dedicated to the literature review (i.e., how scholars use the term 'ecosystem'). The second section will present and contextualise the case study (the French public infrastructure for open scholarly communication in the social sciences and humanities, OpenEdition). The third section will present the results of the survey and interviews (i.e., how infrastructure practitioners use the term 'ecosystem'). Finally, the fourth section calls for an ecology of infrastructure whose function is to articulate the two previous levels (i.e., how I use the term 'ecosystem').

1. Ecologies of Infrastructure

The emergence of ecological notions in the understanding of infrastructure can be traced back to the birth of 'infrastructure studies':[3] in their 1996 seminal article, Susan Leigh Star and Karen Ruhleder indeed called for an 'ecology of infrastructure' paying specific attention 'to the delicate balance of language and practice across communities and parts of organizations' (Star and Ruhleder 1996: 117). Explicitly drawing on Gregory Bateson's *Steps Toward an Ecology of Mind* (1978), Star and Ruhleder were also influenced by Everett C. Hughes' 'human ecology' in symbolic interactionism (Hughes 1984). Furthermore, and although they claimed that their ecology 'is not meant to imply either a biological approach or a closed, functional systemic' (Star and Ruhleder 1996: 117), Star and Ruhleder's approach was also inspired by the ecological science itself: the Long-Term Ecological Research network (LTER) was and still is the archetypal case study of an infrastructure.

Tracing the full genealogy of such a semantic field and its uses is a long and complex task (Mounier and Dumas Primbault 2023) that will be expanded in a future publication. Interestingly enough, the fate of ecological notions was not reserved to infrastructure studies: media studies (McLuhan 1964; Fuller 2005; Taffel 2019)—especially with the advent of the internet (Kling and Scacchi 1982; Huberman 2001)—,

3 In the late 1950s, the philosopher Gilbert Simondon made use of the concept of 'milieu' to understand technology (Simondon 2017), although it cannot be said to be an ecological understanding of socio-technical systems. See section 4.

science studies (Altman and Cohen 2022)—specifically open access (Jaime et al. 2021), open science (Thibault et al. 2023), and citizen science (Jaeger et al. 2023)—, or business literature (Davenport and Prusak 1997; Cobben et al. 2022) made use of ecology related concepts in many very different ways that later infused policy documents (ESFRI 2021; MESRI 2023) as well as common and professional parlance within infrastructures at large.

Among the many roots of the uptake of ecological notions outside the field of ecology itself, one field has had effects on the understanding of infrastructure that is not solely discursive: computing. Indeed, from a media studies perspective, the computer, and the specific materialities of the digital, have upended work practices, infrastructures, information systems, knowledge orders, and the understandings we have of them.

What Jean-Christophe Plantin et al. (2018) called the 'splintering' of modern knowledge infrastructures results primarily in the irruption of the digital within previously integrated and recognisable "black boxes" such as publishing houses, libraries, and bookshops in the case of scientific publishing. Under the emerging digital regime, these established entities have been compelled to adapt, accommodating a reorganisation of work, skills, and professions driven by the advent of new platforms—including within the domain of science (da Silva Neto and Chiarini 2023; Fecher et al. 2024). Plantin et al. (2016) identify the emergence of ecological dynamics with the advent of this new architecture of smaller interconnected ever-evolving building blocks:

> Because they integrate many semi-independent systems, internetworks can only rarely be designed, controlled, or standardised from above; instead, fully developed infrastructures are complex ecologies whose components must continually adapt to each other's ongoing change. (Plantin et al. 2016: 296)

Adopting a general perspective, José van Dijck (2020) describes the global 'platform ecosystem' using the 'tree' as a 'constitutive metaphor' to

> help make sense of information systems as complex structures whose operative power is wielded through hierarchical and interdependent layers; these layers intertwine visibly and invisibly, belowground as well as aboveground, horizontally and also vertically. (van Dijck 2020: 2802)

The advent of the digital led both to the reshuffling of modern infrastructures and to the awareness that infrastructures—traditional and digital—have always been fragile and in tension. Between breaks and continuities, I believe that this (new) infrastructural regime requires a specific model. Previous concepts such as 'large technical system' (e.g., Hughes 1983, for electrical networks) dealt with infrastructures that were 'designed, controlled, or standardized from above' (Plantin et al. 2016: 296). Consequently, infrastructure studies swiftly turned towards a more processual understanding, using the verb 'to infrastructure' (Star and Bowker 2002) or the gerund infrastructur*ing* (e.g., Karasti and Baker 2004).

The term 'ecosystem' in particular has appeared over the past decade and seems to be gradually replacing that of 'infrastructure' in the singular. Following the political reappraisal of ecology in sciences and technologies by Isabelle Stengers (1997), Bonnie Nardi and Vicki O'Day (1999); and more recently Arnaud Orain (2023), I believe there can be an analytical use of ecosystem in an 'ecology of infrastructure.' With Ludovic Duhem (2017), I believe that:

> [...] the idea that ecology is irreducible to the scientific study of ecosystems and the commitment to the protection of nature, and that it must therefore be understood in a broad sense as a relational, dynamic, scalar, and complex approach that can be applied not only to natural environments but also to artificial ones, and in particular to the digital environment, which has now become the associated milieu of our human existence, *i.e.* that which gives new conditions and meanings to our ways of thinking and acting. (Duhem 2017)

This contribution goes one step in that direction, attempting to translate practitioners' ecosystemic frames of experience into an ecological framework in order to better understand how they perceive and act upon the political, technical, infrastructural dynamics of their surrounding environment.

2. Case Study

Today, OpenEdition (OE) is a team exceeding seventy people developing and maintaining an infrastructure comprised of four online platforms

dedicated to open scholarly communication in the humanities and social sciences: Journals, which hosts about 650 journals in open access; Books, with almost 15,000 books in open access from around 140 publishing houses; Calenda, to freely advertise scientific events; and Hypothèses, home of more than 5,000 scientific open access blogs globally.[4]

Established in 1999 as Revues.org, a website designed to host and disseminate French journals in the humanities and social sciences, OE has evolved over time into a comprehensive open scholarly communication infrastructure. Originating as a grassroots initiative from a small French university (Avignon Université), led by a PhD student seeking to enhance the visibility of local history journals online, OE has undergone a process of institutionalisation over two decades.

Revues.org gradually diversified its funding sources, securing support from three additional institutions (CNRS, Aix-Marseille Université and EHESS) and receiving funding from the Ministry of Higher Education and Research. The organisation, renamed OpenEdition in 2011 to reflect its expanded scope, was included in 2016 in the 'national roadmap of research infrastructures.' Being listed alongside synchrotrons, oceanographic fleets, telescopes, and other substantial instruments had a profound influence on the organisation's nature, shifting it definitively from a flexible network to a more structured entity.

However, OE was never formally incorporated, continuing its operations as a 'joint unit' supported by the same four institutions and the Research Ministry. This arrangement has ramifications for the infrastructure's governance structure, norms, and practices. They must constantly align with and adhere to the norms and practices of its supporting institutions. For instance, no staff member is directly employed by OE. Everyone is an employee of one of the supporting institutions, which provide their personnel in-kind to OE.

In the course of its institutionalisation, governance structures evolved from a community-led endeavour focusing on and driven by researchers represented by a scientific board, to a higher-scale, institutionally backed public service operating under more pressing

4 Briefly anticipating the results of the survey, let us also note that OE is overwhelmingly perceived by its agents as an infrastructure that provides a set of services to a community of users. It is also seen as relatively stable, yet evolving, as well as fragile and living with tensions.

constraints from government agencies, funding bodies, publishers, and library consortia (Gatti et al. 2025: 28–29). Sovereignty on strategic and policy matters shifted from the scientific board to a steering committee mostly composed of representatives of the backing institutions and whose power, as we will see, is felt as a 'top-down process.' For the agents of OE, this integration within a much broader environment driven by specific dynamics and governance results in some opportunities, as well as a growing number of constraints and pressures to which they have to adapt in the exercise of their profession.

Tensions arise from this heterogeneity: although all are French public institutions subject to the same legal framework, they are diverse in nature. In its daily operations, OE must navigate four distinct situations: four different HR management systems, four budgets, four authentication systems, and four different management rules—while operating in a general context of chronic underfunding and a serious lack of personnel. Indeed, project-based funding represents an important part of revenues. Under the constraints of multiple funding bodies with their own agendas, projects usually entail developing new features at the expense of regular maintenance while they entrench precarity by favouring short fixed-term contracts, leading to a significant level of turnover with an average duration of stay of about three years.[5] This accounts in part for the infrastructure's fragility while hindering its ability to adapt.

In this context, my objective is to understand better if and why an analytical framework based on ecological concepts is mobilised in practice by OE agents.[6] Furthermore, I would like to understand how this use attests to power dynamics both within OE and with external stakeholders. This investigation is based on a survey sent to all OE agents, followed by four semi-structured interviews with selected agents.[7]

5 Since 2017, fifty fixed-term contract agents have left OE.

6 This is part of a broader ethnography of the infrastructure on which I draw elements to contextualise and interpret the present study.

7 The survey consisted of four unequal sections of variable lengths depending on the answers: i) Profile (four to five questions); ii) The term 'ecosystem' (seven to eleven questions); iii) Your perception of OE (five questions); iv) Follow-up (one to two questions). The survey was hosted on Limesurvey and its template is available at Dumas Primbault (2025). We received thirty full responses to the survey, which is about fifty percent of the total size of the unit; they are a representative sample in terms of departments, skills, and seniority.

Quotes from free fields in the survey are here denoted by [FFS].

The survey and interviews were devised according to Erving Goffman's (1974) 'frame analysis,' i.e., I endeavoured to analyse the metaphors and roots thereof, mobilised by actors to make sense of their professional environment, to circulate messages to counterparts, and to guide their action within it.[8] The approach was both deductive—specifically probing the term 'ecosystem' and associated ecological notions—and inductive, as, in the course of the inquiry, the *a priori* ecosystemic frame was refined and pluralised. As we will see, this methodology will allow us not only to highlight how agents understand their situation, but also how they organise their activity—e.g., how to address a collaborator, when to perform an action in a sequence, etc.—and, eventually, how the ecosystemic frames may blur natural and social frames. Where it applied, I also prolonged our analysis in terms of 'regimes of justification' (Boltanski and Thévenot 1991), that is, coherent sets of arguments and norms mobilised by actors to justify their action (in this case their use or not of the term 'ecosystem').

3. OpenEdition within its 'Ecosystem'

Let us now delve into the answers to the survey and complement them with the interviews in order to qualify the types of uses and meanings of the term 'ecosystem' in the context of OE and its surrounding environment.

First and foremost, one third (ten) of the respondents say they do not use the term 'ecosystem' at all—most of them for intentional reasons:

Semi-structured interviews were then realised undertaken with four agents representative of the four groups detailed below. They consisted of four sections as part of a one-hour long discussion that lasted for an hour on average: i) Profile and background (~10 mins); ii) Discuss three personalised questions regarding the interviewee's answers to the survey (~30 mins); iii) Show the interviewee their personal 'map of OE's surroundings' as answered in the survey and ask for a comment; repeat with the general map of aggregated answers (~10 mins); iv) Present the interviewee with general preliminary results and ask for a comment (~10 mins). The interviews were recorded and transcribed. The protocol and transcripts are available at Dumas Primbault (2025).

Quotes from the four interviewees are here denoted [ITW#].

This study was endeavoured undertaken within the French context; testimonies were translated into English for this contribution; wherever the translation was not accurate, I added the original wording in italics and within square brackets.

8 It is worth noting that frame analysis has previously been applied to the concept of 'open' by Nathaniel Tkacz (2015) and Denisse Albornoz et al. (2018).

because there exist more appropriate synonyms (mostly 'infrastructure' and 'system'); because it does not mean anything remotely concrete for them; because it is merely a 'fashionable' term; or because their interlocutors do not use it either. Of specific interest here concerning the politics of the infrastructure are respondents who claim to not use the term because 'it conveys ideas they do not share.' Two of them extensively justified this choice in a dedicated text box. One of them regrets that the use of such a term alludes to the naturalisation of socio-technical dynamics, thereby considered objective and immutable, and the reciprocal engineering of natural ecosystems—calling on the 'Green World' (Rougemont 2017) or the 'Natural World' (Demil et al. 2024) as regimes of justification. Contra this perceived reversal of properties, they emphasise the 'political power' to shape the dynamics of infrastructures:

> The notion of a digital ecosystem (for example) and the rules that apply to it are modifiable and can be changed *ex nihilo* by the political, institutional, and economic constructs that humankind wants to create for itself. The danger of applying the term ecosystem to other objects is that it implies that we can play with the biological ecosystem and change its rules as we please, just as we can in other spheres. Unfortunately, this is not the case. We need to accept that we are just as powerless to change the rules of our environment (biological and physical) as we are to convince ourselves of our political power to change human-made 'ecosystems' (research, digital, etc.). [FFS]

More specifically addressing matters of openness in relation to ecosystems, another loquacious respondent argues that the use of the term precisely denotes a failure of open science—thereby opposing a 'Domestic World' to a supposed 'Civic World':

> In my mind, ecosystem means a closed community [*entre soi*]. It's a way of acknowledging that open science is carried out by a closed community of stakeholders, and at the same time acknowledging that openness is a top-down process: from the holders of knowledge to the rest of the population. But perhaps what the notion of ecosystem underlines is precisely the limits of a not-so-open science (top-down knowledge, difficulties in applying identical open science principles in different regional contexts, etc.)? [FFS]

Chafing under the double bind to adapt on the one hand, and to abide by top-down processes in precarious conditions on the other, these two respondents refuse to use the term ecosystem because it naturalises the

fragility of the infrastructure—while it is due to economic and political strategies—and thereby eschews their power to act, while said strategies could be reverted or mitigated. These arguments echo other political criticisms of the notion of 'ecosystem' as being a neoliberal naturalisation of socio-technical dynamics reduced to the survival of the fittest in the competition for limited resources in a closed and self-sustaining milieu (e.g., Beatty 2014; Norris and Suomela 2017; Stiegler 2019).

Among the other two thirds (twenty) agents who use the term 'ecosystem,' more than half of them use it as a synonym for either 'environment,' 'system,' 'network,' 'platform,' or 'infrastructure.' Depending on the context of its use and the skills and profession of the respondents, these synonyms do not have the same meaning. I have identified three different semantic fields.[9]

In software development, it relates to the interconnectedness or modularity of multiple components and building blocks through protocols and APIs (e.g., 'In a software environment, for example, an ecosystem could be a set of applications (software), whose responsibilities are different but which work together for the same purpose: network, database, data formatting, message communication, cache, data storage, user interface, etc.' [FFS]).

In publishing, it relates to the broad production, edition, and circulation of information in different formats (e.g., 'the environment specific to the life of books' [FFS], 'editorial workflow' [FFS], 'bibliodiversity' [FFS], 'publication processes' [FFS]).

In communication, it is used in discussions with a host of heterogeneous actors outside the infrastructure (e.g., other infrastructures; users in training; the institutions of open science, such as the ministry of higher education and research or the European research council; or a broader audience in public relations).

Despite these well-identified uses, a significant number of respondents who make use of the term 'ecosystem' were somewhat critical of it in the comments. Some categorise it as 'open science jargon' [FFS] or 'use it to fit the 'mould' and please the people I'm talking to.' [FFS] Another agent phrased their political disagreement using the same words as one non-user mentioned above: 'generally speaking, I'm not in favour of

9 Other ecosystems such as the 'data ecosystem' are also mentioned in passing.

applying biologising or naturalising concepts to human constructs that are full of power relations' [FFS]. Overall, respondents who use the term do so 'for lack of a better word or out of convenience' [FFS], for example 'rather than talking about the environment' [FFS]. Between intentional rejection, overwhelming use as a synonym in context, and reluctance to use it, it is important to note that the term 'ecosystem' is very seldom mobilised as a proper word, i.e., not in a figurative or metaphorical way.

When asked about the scale at which the term is relevant, all respondents agree that the infrastructure OE itself cannot be conceived of as an ecosystem—it is not sufficiently large, complex, or heterogeneous. Rather, OE as an infrastructure is perceived as part of one or several wider ecosystems. Here, the previous three semantic fields emerge again: software development with an 'ecosystem of applications [dev] (*sic*)' [FFS]; publishing with the 'ecosystem of scientific publishing' [FFS], 'ecosystem of the book' [FFS], or 'informational ecosystem' [FFS]; and communication with the 'ecosystem of large-scale project (European for example)' [FFS] or 'open science ecosystem' [FFS]. Broader and blurrier, 'research ecosystem' [FFS] and 'digital ecosystem' [FFS] are also mentioned.

Overall, the term is used by agents to situate themselves and their infrastructure as embedded—the first property of infrastructure for Star and Ruhleder (1996)—within a broader, more complex, and more varied context, which has certain effects on their activity—opportunities as much as constraints and pressures—, and on which they could have a certain effect through their activity—if the governance structure accommodated it. Therefore, just like the notion of infrastructure, an 'ecosystem' is relational and could be akin to 'the infrastructure' in the singular—and thus be the object of an 'ecology' (Star and Ruhleder 1996).

This analytical use of the term, which I will detail below, should not be conflated with a full-fledged ecological framework to understand infrastructures. Although one striking exception is one interviewee who expounded his view of infrastructures in context as a 'complex system' in the mathematical sense:

> The term has come into use at a time when we are becoming aware, through the dynamics of systems [of the fragility of ecosystems]—global warming is a prism through which we can reflect on this. The visibility of this complexity [...] means that we are becoming more aware and are

> using more appropriate words to describe a system whose components are interdependent, because a disturbance arriving in a space they share can have deleterious effects on one or other of these components or on the system as a whole. [ITW3]

Nonetheless, the term is not significantly linked to other meaningful ecological notions and concepts. Although 'resources,' 'bibliodiversity,' and 'predatory' are mentioned, they do not convey biological connotations and are not used in a cogent manner together with 'ecosystem.' Moreover, most respondents report using the term 'fairly little internally' [FFS], and mostly with specific interlocutors from outside the infrastructure: during 'training sessions' [FFS] for users, in 'official and public context' [FFS], 'with other open science stakeholders' [FFS], 'with colleagues involved in European projects' [FFS], or 'with stakeholders close to the project' [FFS].

Therefore, 'ecosystem' seems to be mostly mobilised as a boundary object—i.e., a term plastic enough to accommodate diverse, even contradictory definitions, yet robust enough to allow the coordination of heterogeneous stakeholders (Star and Griesemer 1986)—used by agents at the interfaces between the infrastructure and its surroundings. Precisely because it has no explicit, detailed, and shared meaning but is used by a variety of stakeholders to designate vaguely their common environment and its complex dynamic, the term 'ecosystem' allows for the coordination of action in this context. In that case, there is no 'frame alignment'—that is no correspondence-making between differing frames (Snow et al. 1986)—precisely because it is the diversity of frames that ensures the polysemy of the term and its power as a boundary object.

In order to better understand the use of the term as a boundary object, one question in the survey was dedicated to clarifying what entities were in the 'surroundings' of OE and what kind of relationships it had with them. A set of eighteen entities and fourteen types of relationships were proposed. The aggregated results are shown in Figure 7.1, keeping types of relationships selected by more than one third of the respondents (amounting to ten types). During the interviews, subgroups (institutions, users-consumers, and users-producers) were identified and it was decided to merge international organisations with NGOs (amounting to seventeen entities).

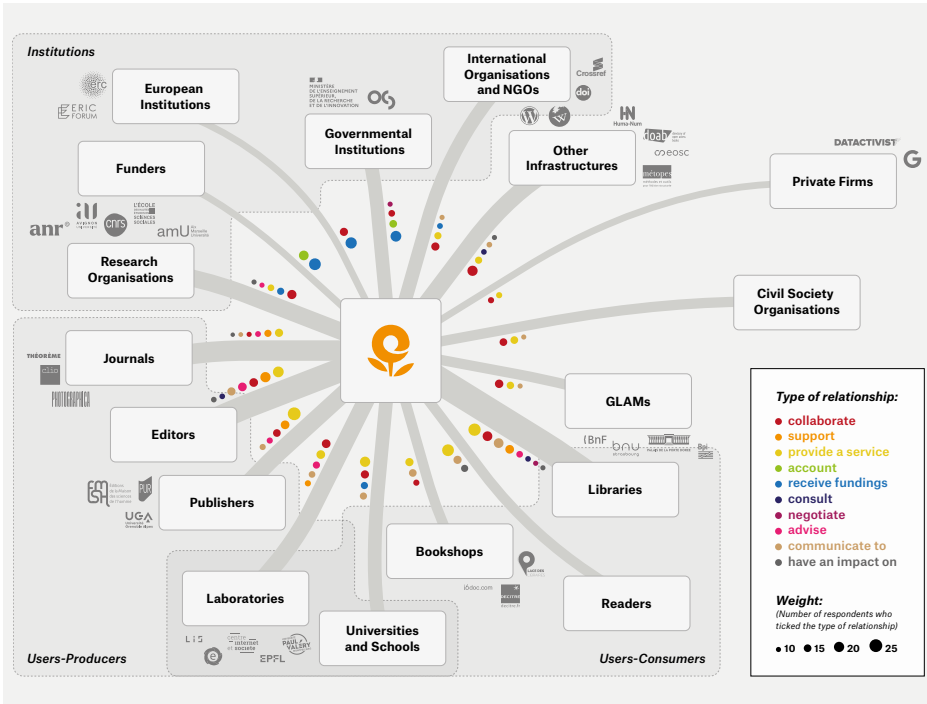

Fig. 7.1 Map of OpenEdition and its surroundings aggregated from the answers of the thirty respondents to the survey when asked to qualify the nature of the relationship between OE and eighteen external entities—only the relationships selected by more than one third of the respondents were kept. Simon Dumas Primbault and Clément Bresch, 1 August 2025, © Clément Bresch.

The type of relationship most mentioned, by far, is 'to collaborate'—including with entities that exert more power and constraint over the infrastructure, such as the backing institutions through the steering committee. Only one interviewee, whose daily activities involve more contact with said institutions, both governmental and European, or with funders, ticked 'to obey.' In this context, they were 'forced' to use the term 'ecosystem' to 'sell the projects':

> What I wanted to try and present each time [to these institutions] was precisely these relationships, i.e., when I had to say how [project_name] fits into the open science ecosystem, it was in fact to explain that [project_name] is there to help make links, to help with research, to help people find scientific resources, to better understand or contextualise a document [...] I inserted myself in this way because I could say that it's

> a tool that serves this research ecosystem [...] we're here to make links, create these relationships and to say that we're trying to articulate all this to facilitate, to help open science [ITW2]

This said, on average, non-reciprocal relationships such as 'obey' or 'govern' are not used to represent OE's links with its surrounding entities. On the contrary, it seems that types of relationships somehow balance each other out: for example, receiving fundings implies either being accountable or providing a service, while consulting implies communicating to.

Although it would need a more detailed qualitative analysis—one respondent commented that it 'only partially (if at all) reflected [their] vision of this ecosystem' [FFS]—, this exploratory semantic field analysis may illustrate a form of fragile equilibrium between interrelated entities. While interdependency is often mentioned in the comments and interviews, it rather emerges as a distributed property in this illustration. And indeed, when asked why this network would be akin to an ecosystem, a considerable number of respondents are reluctant to answer: mapping OE's surroundings is too local a representation to capture an ecosystem, which is a broader more complex environment that cannot be centred on OE. However, most comments agree that this mapping does capture some ecosystemic dynamics: the 'balance' of an 'interconnected' whole [FFS], 'collaboration versus competition' between 'complementary services' [FFS], 'relations of influence' [FFS], and more specifically, the power of the infrastructure to act on its ecosystem: 'It also shows that these interactions can be based on strategic choices, and that OpenEdition can play a part in these choices.' [FFS]

This map of OE's surroundings, coupled with the survey and interviews, points towards the fact that the ecological framing—or refusal thereof—is a tool for OE agents to act at its interface: the infrastructure they work for is essentially open to other interoperable infrastructures, open to a wide variety of stakeholders with differing views on open science, open to shifts in the economic and political context, and open to changes in scientific policies. Under pressure to adapt to this very heterogeneous, dynamic, and expanding context, and faced with the extreme fragility of the infrastructure, agents use or refuse to use the term 'ecosystem' as a way to name and tame this double bind, to navigate, under constraint, their complex environment.

4. For an Ecology of Open Infrastructures

Following up on two respondents who urged me to, first, 'separate the use made of ecosystem for [...] doublespeak by people for whom it may be meaningless' [FFS] and second, 'to use it in an analytical perspective' [FFS], let us now try to arrive at a working definition that may help us understand a specific dynamic. Answers to the survey—specifically free-text fields—and semi-directed interviews allowed me to unearth a bundle of corroborating evidence that enabled me to abstract a definition of the term 'ecosystem' common to all analytical uses of it. Confronting the results of this brief case study with the literature in infrastructure studies (Mounier and Dumas Primbault 2023), I would like to venture an analytical definition of an 'ecosystem' in the context of open science and digital knowledge infrastructures.

Indeed, agents using the term 'ecosystem' in an analytical way express the need for a more complex and nuanced understanding of infrastructures and their environments—and thereby echo concerns about a new infrastructural regime outlined in the introduction: an infrastructure is more than just its socio-technical scaffolding—i.e., the legal and material infrastructure, the 'brick-and-mortar' part, the platforms and the agents—and it maintains complex and dynamic relationships with its surroundings.

The philosopher Gilbert Simondon was confronted with an analogical issue when trying to theorise the dialectical relationship between technical objects and their environment: for Simondon, the associated milieu of a technical being is composed of all the 'elements surrounding' it (Simondon 2017: 59); it is both produced by the technical being and, reciprocally, becomes the condition of possibility for its 'individuation.' I propose to reappraise the concept of 'associated milieu' and apply it to specific socio-technical arrangements—infrastructures (Mounier and Dumas Primbault 2023). Building on the reappraisal of Simondon's mecanology to understand the digital era (Duhem 2017), we can conceive of infrastructures as surrounded by an associated milieu—natural resources, its (future) users, other infrastructures, institutions—and of governance as the organisation of these elements into an assemblage (for further developments on the governance of infrastructure, see Mounier and Dumas Primbault 2023). We can consequently define an

infrastructure and its associated milieu as a governed assemblage of stakeholders/socio-technical devices/policies/norms made temporarily stable and coherent by balancing its inherent tensions, and that supports a specific set of activities (e.g., research or knowledge sharing).

For Simondon, this temporary stability is essentially a 'metastability': the dialectic dynamic between a technical object and its milieu can always evolve, when inherent tensions are liberated, towards a new state of metastable individuation. While stability is death, metastability is the power to react and adapt to internal and external perturbations. From this perspective, an infrastructure like OE must accommodate a metastable state balanced between acting as an official research infrastructure—i.e., invisibly and faultlessly supporting scholarly activity—and behaving as a changing milieu—i.e., adapting to the interconnected nature of knowledge, the changing political stakes, the ever evolving technical context (see Stiegler 2019). This is a balancing act that may be perceived as a paradox or a double bind in a context of enduring and growing fragility.

Indeed, let me emphasise here that metastability should not be conflated with fragility.[10] On the contrary, fragility leads to instability, while to maintain a socio-technical being in a metastable state requires regular funding, secure personnel, and a governance that involves all stakeholders—agents included—and not merely institutional support. Metastability is a property to be nurtured, sustained, even strengthened for infrastructures to continue to thrive rather than merely survive. If openness applies to the very structure and dynamic of the infrastructure and its milieu, fragility is its enemy.

The 'ecosystem', akin to the infrastructure in the singular, can consequently be defined as a higher scale where entities and their environment are dynamically interwoven through their reciprocal milieux—technical, social, informational. In this context, we can therefore define an ecosystem as an environment of heterogeneous entities—infrastructures, institutions, associations—that have become interdependent and whose dynamic is therefore complex (involving

10 And while an ecological perspective may be useful to understand the metastability of an infrastructure, its fragility can well be understood by referring to more traditional notions of the sociology of organisation, notably in a neoliberal context for public research.

path-dependencies, ripple effects, resilience, side effects) and results from the fragile equilibrium of tensions.

The emphasis put on the fragility of ecosystems and their specific dynamic highlights one essential tension between i) the power of infrastructures to either reinforce existing socio-political dynamics or foster new ones within their ecosystem; and ii) the asymmetry of interdependencies between entities in an ungoverned ecosystem—thereby constraining the technical and political power of infrastructures to act.

The infrastructure, in the formal sense, together with its associated milieu, thus form an ecological unity that is governed both by 'hard' means—such as statutes, a hierarchy, a steering and a scientific committee, conditions of use, which are formalised and inscribed in its functioning—and by 'soft' means—such as standards, layers of technical norms, best practices, project funding, which are negotiated at the interface with the ecosystem through its associated milieu. The infrastructure therefore can be conceived of as a governed milieu navigating within an ecosystem, and open to transformation.

Conclusion

Seldom defined yet widely employed, the term 'ecosystem' is multifaceted and challenging to pin down. At OE, its usage spans three practice fields—software development, information and publishing, and institutional open science—and serves three distinct purposes, adapted to specific contexts.

Firstly, 'ecosystem' can be used rather indiscriminately, as a synonym for an infrastructure, a platform, a network, an environment, but it has come to replace these terms in the contemporary parlance—in which case it can be used as window-dressing for old things. Secondly, it can be used as a boundary object when it is purposefully used in a vague manner with partners, collaborators, stakeholders outside the infrastructure that may not share a definition but need a dedicated term to coordinate their collective action in a shared context. Finally, 'ecosystem' can be mobilised as an analytical concept, most frequently outside any fully fledged analytical framework, to designate the complex dynamic of broader surroundings and to describe the ways in which

they constrain action and, reciprocally, in what ways they can be shaped and altered by action.

To which we must add an intentional refusal to use the term for practical reasons—there are more appropriate terms, it does not mean anything concrete—and for political motives—it conveys inappropriate ideologies about, e.g., the confusion between biological and human-made systems (akin to green-washing), or about the closedness of open science (acknowledging enclosures, or naturalising work organisation).

Besides the mere window-dressing of age-old objects and practices, or its use as a boundary object, the term 'ecosystem' also reflects the genuine designation of a (new) infrastructural dynamic or configuration. This analytical use of the term by OE agents is a way for them to frame what they perceive as changes in the infrastructural regime.[11] Yet, these dynamics are not perceived as recent by the two respondents who argued that the term 'ecosystem' could designate a new configuration.[12] For them, the emergence of 'ecosystem' reflects the awareness of an already existing fragility, and its use expresses the intention to act accordingly—similar to the interviewee who mentioned global warming as such a realisation. This realisation of fragility comes with an awareness of the need to constantly adapt to or resist permanent evolution.[13]

Building on the infrastructure practitioners' frame of experience and their understanding OE as a governed milieu within an ecosystem, this ecological perspective also reminds us of the prescriptive nature of the infrastructure—it is an 'invisible form of governance' (Chan

11 For example, one developer suspects the term 'ecosystem' mainly came from IT companies who could thereby market a modular digital environment with shiny notions. Beyond mere devices, this logic extends to Agile software development, they say, and to the organisation of work in all fields: 'I have the impression that IT is one of the modern precursors of new methods of management and work organisation, just as the car industry was at the time, so there are a lot of terms that are used [that come from there], and we shouldn't be fooled by that.' [ITW4]

12 One interviewee, a former bookseller for ten years in the early 2000s, and who 'saw the arrival of the digital' and its effects on what was previously called the 'book chain,' said: 'I didn't use the term much, before the 2000s, I think it was only used in the field of ecology. [But] my whole life in the book trade has been something fragile that has its ins and outs and that you can't do just anything. What I brought to OpenEdition was this knowledge [...] that if you do this or that, you're going to destabilise this or that, and the overall balance is likely to suffer. [...] What I like about my job is that after ten years, nothing has settled or stabilised' [ITW1].

13 As another interviewee stated: 'we must always reaffirm what we stand for, what we work for, what we believe in' [ITW2].

2019)—, therefore of its power to act on its surroundings, to enforce norms and shape practices, to partake in the redistribution of skills and the reorganisation of work.[14] Indeed, like other infrastructures, OE is both governed by its surroundings—having to respond to national and international open science policies or to navigate the changing economy of scientific publishing—and governs its surroundings by partaking in the development of a broader infrastructure at the European level or simply by providing tools that technically enforce norms. For example, the editorial and epistemic criteria that scientific journals must abide by in order to be hosted by OE have had a longstanding positive structural effect on the diversity, quality, and integrity of the publishing field in the francophone social sciences. Reciprocally, this editorial and epistemic governance tends to marginalise journals, and thereby knowledges, from the Souths, establishing open science from a Western-centred perspective.[15]

The decision to use or refuse the term 'ecosystem' by OE agents is one of the ways they frame this reciprocal governance; one of the ways they acknowledge their infrastructure as a political entity—both endowed with the power to shape science and society, and in turn constrained by a longer political history of knowledge infrastructures and systems of production—and acknowledge the politics of its surroundings, which include entities guided by other policies, enacting different values, and sometimes competing definitions of openness.

The term 'ecosystem' thereby becomes a tool for agents, not only to frame, but also to navigate—literally to govern themselves at—the interface that links OE to its broader surroundings. It is sometimes a means to address political matters head-on by promoting specific values—such as when refusing the use of the term or when advocating a specific definition that emphasises diversity and collaborative interdependencies. At other times, the term 'ecosystem' can be a tool to bypass politics completely—for example when using it as a boundary

14 Note that further work on this topic involves tracing ecological notions more broadly, in a broader corpus (in progress), studying other open infrastructures with the same protocol, and devising a genuinely novel methodology to shed light on this specific infrastructural regime for a proper 'ecology of infrastructures.'

15 Further research should endeavour to shed light on how OpenEdition enforces a specific definition of openness, i.e. is a prescriptive infrastructure that can either reinforce existing socio-political dynamics or foster new ones within its ecosystem.

object to coordinate action between potentially diverging stakeholders without having to find a common definition or common values.

The ecology of infrastructure is the study of such dynamics. By situating open infrastructures within ecological thinking, we gain a richer understanding of their resilience, their vulnerabilities, and the forms of care and governance needed to sustain them (see also Mounier and Dumas Primbault 2023). Indeed, understanding open infrastructures through the lens of ecosystems or ecologies foregrounds their relational, adaptive, and interdependent nature. Rather than being static or self-contained, these infrastructures maintain a state of metastability—a dynamic balance that allows for continuity amid change. This ecological framing highlights how open infrastructures survive by absorbing shifts in policy, funding, and technology while trying to maintain functional coherence. In this sense, metastability emerges not as a fixed trait, but as an ongoing capacity to leverage tension and support collective adaptability. Note that this capacity is itself very fragile and under the threat of underfunding and lack of personnel in an economic and political context where institutional constraints become double binds.

Understanding OE as a governed milieu embedded in a broader ecosystem—where interdependencies and consequent power relations can be highly asymmetrical—is a way to acknowledge that this open infrastructure is one of the loci for the political negotiation of what open science is, and more broadly of what 'open' means.

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8. The Politics of Infrastructuring Inclusivity: DOAJ and its Ambassador Programme

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Introduction

The Directory of Open Access Journals (DOAJ), founded in 2003 to index open access (OA) journals, now includes more than 22,000 titles across 139 countries and 89 languages. Journals apply for inclusion against community-developed criteria. This chapter examines the tensions between setting global standards and fostering inclusivity in scholarly publishing, presenting DOAJ as a global open knowledge infrastructure embedded in the politics of knowledge production. Drawing on science and technology studies (STS), critical information studies, and epistemic justice literature, especially Bowker and Star's (2000) work on infrastructuring and classification, and Miranda Fricker's (2007) concept of epistemic injustice, we analyse how DOAJ balances standardisation and inclusivity through its community-led Ambassador Programme (AP).

We first outline key challenges in scholarly publishing, particularly those related to global inequities and epistemic injustice, then trace DOAJ's origins and evolution, including the development of the AP. Finally, the chapter discusses how a community-led organisation like DOAJ seeks to mitigate epistemic injustices, using the AP as a case study of inclusive infrastructuring.

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The Geopolitics of Knowledge: Classification, Standards, and Epistemic Injustice

DOAJ operates as a knowledge infrastructure—a living constellation of tools, standards and communities whose interactions shape how scholarly work is validated, made visible, and used. Knowledge infrastructures are sometimes regarded as neutral, apolitical, or inherently beneficial for the distribution of knowledge. However, they often cater to the interests, practices, and needs of specific groups, unintentionally reinforcing global power imbalances (Chan et al. 2020). Some scholars have raised concerns about how Western-centred platforms and tools for indexing and disseminating academic content are designed to prioritise the agendas of stakeholders in high-income countries, thereby perpetuating global asymmetries in the circulation of knowledge (Beigel 2014; Roh et al. 2020).

The supposed neutrality of infrastructures often obscures the political and ethical tensions involved in maintaining and negotiating them, particularly in relation to categorical work—the labour of creating, sustaining, and contesting classification systems (Bowker and Star 2000). We argue that DOAJ has adopted a participatory approach to establishing standards for scholarly journals, responsive to the diverse needs of global communities of practice. In this sense, we conceptualise DOAJ as an inclusive knowledge infrastructure—defined as 'the tools, platforms, networks and other socio-technical mechanisms that deliberately allow for multiple forms of participation among a diverse set of actors, and that purposefully acknowledge and seek to redress power relations within a given context' (Okune et al. 2019: 3).

To paraphrase Bowker and Star (2000), standard-setting inevitably excludes or silences someone—and this can lead to unjustified forms of judgment. In scholarly publishing, the terms questionable publishing or predatory journals are often used to describe journals that lack proper publishing procedures or do not operate in good faith (Shen and Björk 2015). However, many of the features associated with these labels are also found in journals that are under-resourced and based in low- and middle-income countries (LMICs). This can result in unfair judgments that risk perpetuating epistemic injustices (Albornoz et al. 2020).

Miranda Fricker's foundational book, *Epistemic Injustice: Power and the*

Ethics of Knowing (2007), highlights the unfair treatment of individuals and communities as legitimate knowers in different contexts. The concept of epistemic injustice can be summarised as 'having one's meaning or contributions systematically distorted, misheard, or misrepresented' (Kidd et al. 2017: 1). In the global scholarly publishing landscape, epistemic injustice arises when standards of quality and excellence are unilaterally defined by dominant actors in the scientific publishing industry. Journals with publishing practices that deviate from these standards are often excluded or perceived as lower in quality. For example, in Africa, the low levels of digitisation of journals make it particularly challenging for many editorial teams to interpret indexing requirements, resulting in the exclusion of many African journals from major indexes (Aldirdiri, 2024).

Okune et al. (2019: 16) argue that knowledge infrastructures must recognise diverse human needs and intentionally address power imbalances. DOAJ exemplifies this inclusive infrastructure, striving to counter epistemic injustices while grappling with the challenge of maintaining standards without reinforcing the very inequities it seeks to redress. This tension reflects Bowker and Star's (2000: 34) notion of infrastructural inversion—the deep interdependence between technical standards and the politics of knowledge production.

The next section outlines a brief history of DOAJ, with a focus on how the indexing criteria has developed, highlighting the tensions DOAJ faces in balancing the setting of global standards with the promotion of inclusivity in scholarly publishing.

Building a Global Infrastructure: The Categorical work of DOAJ

Bowker and Star (2000) define categorical work as management of the mismatches between standards and anomalies in classification systems. DOAJ's categorical work involves making choices about what is included and excluded in its set of indexing criteria. This section provides an overview of the development of these criteria since the directory's inception.

The concept of a directory of OA journals was first proposed at the 2002 Nordic Conference on Scholarly Communication, held at Lund University, Sweden. DOAJ was founded the following year, in 2003, by Lars

Bjørnshauge, the Director of Libraries at Lund University. The directory was launched with a list of over 300 journals, curated by Bo-Christer Björk, and quickly gained interest and support from the OA community.

What began as a project funded by the Open Society Institute (OSI) and Scholarly Publishing and Academic Resources Coalition (SPARC) soon evolved into a widely used service relied upon by the global academic to find trusted OA journals (Johansson and Wahlgren 2008). In its early years, journals were suggested to the directory through a form on the DOAJ website. Suggestions were manually reviewed by librarians at Lund University to ensure that the journals adhered to the definition of OA, established by the Budapest Open Access Initiative—free to access and free to reuse (Budapest Open Access Initiative 2002).

Initially, most journals in DOAJ published primarily in English, reflecting the prevailing bias in global science communication that positions English as the 'language of science' (del Rio Riande and Lujano Vilchis 2024). Of the original list, only eleven journals accepted articles in languages other than English, and only two journals published exclusively in a non-English language.

To fulfil the original vision of being a global index, DOAJ required local experts who could review journal suggestions in multiple languages. A network of global volunteers—referred to as 'editors'—became an integral part of DOAJ's structure, with the number of represented countries and languages steadily increasing. Today, DOAJ has over 100 volunteer editors and indexes more than 22,000 journals from 139 countries in 89 languages. The work of these editors is coordinated by Managing Editors who oversee regional or language-specific groups.

DOAJ's criteria today differ significantly from those in 2003. In its early years, DOAJ had four main criteria, 1) information coverage (subject, target group, and types of content), 2) access (free for readers, free registration, and no embargo), 3) metadata, and 4) quality (an editorial board and/or a peer-review system). By 2008, the criteria had evolved to include peer review or editorial control, ongoing publication, full-text availability for all content, and a valid International Standard Serial Number (ISSN) (Johansson and Wahlgren, 2008). By 2013, the directory had grown to include almost 10,000 journals, reflecting the rapid expansion of OA publishing (Shen and Ball 2024). That same year, the service transitioned from Lund University to a new UK-based

Community Interest Company, IS4OA (Infrastructure Services for Open Access C.I.C) (Infrastructure Services for Open Access 2012). In 2025, DOAJ moved its operations to Denmark under a newly established DOAJ Foundation, a step taken to strengthen its governance structures and enhance long-term sustainability (DOAJ 2025a).

Around ten years after the launch, developments in scholarly publishing—including increasing concerns about questionable publishing practices—prompted DOAJ to revise its criteria and implement a more rigorous screening process. The emergence of different models of OA also highlighted the need to define what types of OA journals DOAJ would index. In 2013, DOAJ invited feedback from the community on a draft set of updated criteria (Wojick 2013).

In 2014, following more than 200 comments from the community, the new criteria were officially launched. Due to the significant changes, the 10,000 journals already listed in the directory were asked to reapply to ensure they met the updated criteria.

While the reapplication project was ongoing, DOAJ successfully applied for funding from the International Development Research Centre (IDRC) to support the improvement of OA publishing practices in the developing world (Bjørnshauge 2016). This grant enabled DOAJ to create the AP, and recruit local experts to help journals from LMICs understand and adhere to DOAJ's criteria and good publishing practices. The goal was to encourage these journals to apply for DOAJ-indexing and to support regions experiencing challenges related to questionable practices. We will discuss the programme in more detail later in this chapter.

The reapplication project began in January 2015 and concluded in December 2017. By that time, DOAJ had removed 2,058 journals from its index for failing to meet the new criteria and 2,860 journals for not reapplying (DOAJ 2017). DOAJ's indexing process evolved from a simple one-page suggestion form completed by members of the community to an application form comprising approximately fifty questions, to be filled out by the relevant journal editor or manager. The increased complexity of the application form, along with more clearly defined criteria, heightened the need for journals to seek support in meeting these standards.

Today, DOAJ provides support to regions with specific needs, collaborating with local individuals, organisations, and institutions.

A recent example is the support provided to Ukrainian journals, establishing a process to fast-track applications and collaborating with initiatives such as the Supporting Ukrainian Editorial Staff (SUES) project, the Open Ukrainian Citation Index (OUCI), and Research4Life. These efforts aim to increase the visibility, transparency, and impact of all Ukrainian OA journals (Zimba et al. 2025).

The scholarly publishing landscape is complex, constantly evolving, and marked by significant regional variation. Establishing a global standard for OA journals remains a challenging task. DOAJ's evaluation criteria continue to be developed and updated to reflect ongoing changes in scholarly publishing. For example, in 2021, new guidelines were introduced to address high endogeny rates and to limit self-promotion. In 2023, specific criteria for special issues were added to ensure adequate editorial oversight. These additional guidelines are essential both for promoting good practices in OA journals and for clarifying ambiguous cases for the DOAJ team to assess. To ensure the DOAJ criteria are equitable, the directory established an Editorial Policy Advisory Group in 2024. The group is made up of individuals representing trusted organisations working in scholarly publishing who assist the editorial team with publishing policies and practices 'to ensure that DOAJ criteria are effective for the widest range of publishers across the globe' (DOAJ 2025b).

In sum, DOAJ's history illustrates the complex process of infrastructuring open knowledge. From its origins as a simple list to its current status as a global standard, DOAJ has navigated the tensions between inclusivity and quality, and between local needs and global standards. The evolution of its criteria and its commitment to multilingualism and inclusivity, reflect an ongoing effort to address the political and ethical challenges of open access. The AP is a key strategy in this ongoing process of infrastructuring inclusivity.

What Defines an Infrastructure? The Growth of DOAJ as a Community-led Infrastructure

We view the DOAJ as a living infrastructure co-constructed and maintained by a diverse global community. This perspective draws attention to the often-invisible labour, decisions, and negotiations that

sustain such systems—work that becomes visible when we examine how DOAJ grows, adapts, and responds to its users. In this section we offer an overview of DOAJ through the lens of the nine key properties of infrastructures proposed by Star (1999).

As a live database, DOAJ is in a constant state of change: journals are added immediately upon acceptance and removed regularly when they no longer meet the required standards. This dynamic maintenance process is a central feature of the infrastructure. The editorial team plays a key role in this ongoing work, routinely checking indexed journals to ensure continued compliance with DOAJ's criteria. Beyond formal review, DOAJ also listens to its user community, responding to concerns by investigating journals or publishers flagged through public discourse or internal monitoring. In this way, DOAJ functions not only as an index but as a responsive system shaped by the practices and trust of its global community. Its sustained annual growth is a testament to the infrastructure's ongoing relevance, credibility, and collaborative stewardship (see Figure 8.1 below)

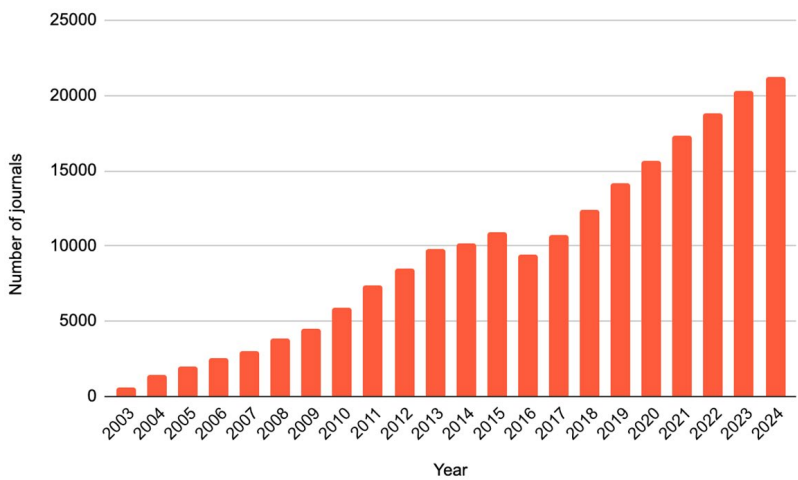

Fig. 8.1 The number of journals indexed in DOAJ from 2003 to 2024 Source: Directory of Open Access Journals.

In *The Ethnography of Infrastructure* (1999), Susan Leigh Star defines infrastructure as having nine key properties: embeddedness,

transparency, reach or scope, learned as a part of a membership, links with conventions of practice, embodiment of standards, built on an installed base, becomes visible upon breakdown, and is fixed in modular increments, not all at once or globally. We argue that DOAJ can be described in terms of all these dimensions.

Two key dimensions that DOAJ exemplifies as an open infrastructure are embeddedness—defined by Star as being 'sunk into and inside of other structures, social arrangements and technologies' (Star, 1999: 381)—and reach and scope, described as 'having a reach beyond a single event or on-site practice' (Star, 1999: 381). DOAJ's user base extends far beyond those visiting the index to browse or check journals. The index is deeply integrated into a range of systems, tools, and workflows, sometimes covertly, as in the case of the Plan S Journal Checker Tool (2023) or library discovery systems, and sometimes overtly, when DOAJ inclusion is a requirement for institutional Article Processing Charges (APC) payments or a criterion for other indexes, like SINTA (Science and Technology Index) in Indonesia or SciELO in Latin America (SINTA 2025; SciELO 2018). Using DOAJ as a proxy for quality reduces manual work for many organisations, and also relates to the transparency dimension which Star (1999) defines as the capacity of infrastructure to support tasks invisibly, without requiring users to relearn the system each time.

Moreover, DOAJ's established position as a source of trusted journals also reflects Star's (1999) property, the embodiment of standards. DOAJ incorporates this dimension both through its criteria—which reflect an unofficial community standard for quality OA journals—and through its integration into other systems, effectively becoming a standard in itself: the DOAJ standard. The community's reliance on DOAJ as both a standard and a system becomes especially apparent when viewed through another of Star's infrastructural dimensions: becomes visible upon breakdown. As noted above, in addition to being embedded in automated systems, DOAJ is also part of many manual workflows. As such, a disruption in DOAJ's operations would likely have an undocumented but widespread ripple effect across the global scholarly community landscape.

A dimension that DOAJ possesses—but has also been tested—is being fixed in modular increments, not all at once or globally.

Infrastructures do not typically undergo sudden transformations. Apart from the reapplication project in 2015, DOAJ's evolution has been slow and organic. Its growth and development have largely stemmed from listening to and observing its community—through its network of volunteers and Ambassadors, board members, and regular consultation with stakeholders. One example of this engagement is the 2024 Community Survey, which led to a retirement of the DOAJ Seal in 2025 (DOAJ 2025c). This approach to evolving infrastructure in response to user input also connects to another of Star's dimensions: links with conventions of community practice, which refers to the alignment of infrastructure with the needs and norms of the community it serves. We see evidence of this throughout DOAJ's history—from its original launch to the reapplication project and the continued refinement of its indexing guidelines. At the core of DOAJ's mission is the indexing of all global OA journals and the promotion of good practices in OA publishing. These objectives reflect Star's dimension of infrastructures being built on an installed base: how infrastructures develop incrementally from existing systems rather than starting over entirely, evolving in response to emerging problems. The reapplication project both exemplifies and slightly challenges this dimension: while it represented a significant reset in terms of redefining criteria, it was also a necessary step for DOAJ to remain aligned with its foundational mission of serving as a trusted global index of quality OA journals.

Star's final dimension, learning as a part of a membership, defines infrastructures as systems that outsiders must learn to navigate over time—as members gradually become more familiar with an infrastructure, they achieve a sense of 'naturalised familiarity.' Though DOAJ is relatively easy to navigate and use, journals seeking to be indexed must develop a deeper understanding of the criteria. In many institutions, librarians or institutional presses are local experts in good OA publishing practices, offering guidance to their local community on the DOAJ and its criteria. This results in various levels of familiarity and expertise of DOAJ across different contexts. One of the key aims of the AP was to support this dimension of learning as a part of a membership in LMICs, and develop local experts who could assist their communities in adopting good publishing practices and preparing journals for DOAJ indexing.

Infrastructuring Inclusivity: The DOAJ Ambassador Programme

One of the original aims of the AP was to improve OA publishing practices in the Global South—particularly in regions where languages other than English are used for research and publishing. The underlying theory of change for the AP is based on the premise that enhancing awareness and building capacity in LMICs can lead to a more equitable OA landscape (Olijhoek et al. 2018) (see the Digital Annex at the end of this chapter).

Many global publishing and OA initiatives, infrastructures, and organisations—such as the Committee on Publication Ethics (COPE), the Open Access Scholarly Publishing Association (OASPA), the World Association of Medical Editors (WAME), and DOAJ—have been developed or established in the Global North. Although these are international organisations, they are often susceptible to operating with a Global North bias unless they actively engage with communities outside their region or country of origin. There are, of course, challenges to hiring and managing staff and volunteers beyond the primary region in which an organisation operates. Time zones, local politics and policies, all contribute to the complexity of building and maintaining a truly global team. Consequently, many non-profits and organisations based within the Global North remain regionally concentrated due to limited resources. DOAJ, however, is committed to being a global, diverse, and multilingual open infrastructure, and has worked towards this goal since its inception. Today, DOAJ operates from Denmark under the DOAJ Foundation but works with contractors and volunteers from more than forty different countries.

As an organisation based within the Global North, within a scholarly publishing ecosystem that is known to exhibit a Global North bias, DOAJ has allocated specific support and resources to regions experiencing hermeneutical epistemic injustice, in order to help mitigate this bias. According to Fricker (2017), hermeneutical injustice occurs when gaps in resources put someone at an unfair disadvantage. By integrating the AP into DOAJ's infrastructure, the organisation sought to ensure that global perspectives, experiences, and voices from other parts of the world would be reflected in its criteria and the ways in which those criteria are interpreted.

In total, fifteen Ambassadors were recruited through an original call that was published on the DOAJ blog (DOAJ 2016). Between 2017 and 2022, twenty-two additional Ambassadors were recruited from various regions around the world, bringing the total number of past and current DOAJ Ambassadors to thirty-seven. Recruitment has taken place either through open calls or by personal invitation.

Originally, Ambassador activities, reporting and meetings were structured and managed within the IDRC-funded project. When the funding ended, Ambassador activities continued more informally, and some Ambassadors chose to continue their work on a voluntary basis—responding to the needs of their community ad hoc. As the role became voluntary, the AP also expanded organically, extending its scope beyond LMICs. Due to the programme's organic growth and limited resources, activities were not consistently monitored. Nevertheless, there is indication that the Ambassadors' work has had a significant impact in certain regions. For example, the number of journals from African countries listed in DOAJ increased from 268 in February 2022 to 723 in September 2025—although it is acknowledged that the coverage remains low compared to other regions. The AP forms an important part of DOAJ's infrastructural efforts to address epistemic injustices in science. Accordingly, the programme aims to support local experts in LMICs to advocate for and promote ethical practices in scholarly publishing, thereby contributing to a more inclusive and transparent publishing environment.

By 2024, the OA landscape had changed significantly since the launch of the AP. Developments such as the inclusion of OA requirements in funder policies in the Global North, the increased prevalence of Article Processing Charges (APCs), and the rise of read-and-publish agreements between research institutions and large commercial publishers contributed to further imbalances in scholarly publishing—favouring the Global North (Kiesewetter 2020). These changes also lead to greater global awareness of the need for equity and diversity in OA. At the same time, the AP had continued to expand, including regions beyond its original scope. In response, DOAJ initiated a review of the programme to reevaluate its goals and requirements, and to assess the resources and structure needed to align it with DOAJ's strategic objectives (DOAJ 2023). The purpose of the review was to

highlight the programme's impact in LMICs and to ensure that the AP is a well-integrated, structured component of DOAJ—emphasising that Ambassadors are essential to DOAJ's identity as a truly global organisation, with power, decision-making, and influence shared across international participants.

The AP, therefore, is more than just an outreach initiative; it is a vital component of DOAJ's ongoing effort to build a more inclusive and equitable knowledge infrastructure. The work of the Ambassadors—translating criteria, supporting local journals, and advocating for OA—is a form of invisible and articulation work (Bowker and Star, 2000) that bridges the gap between global standards and local realities. By engaging with diverse communities, the programme helps mitigate the epistemic injustices often embedded in Western-centric infrastructures. The following review of the programme provides a detailed look at how this infrastructuring work unfolds in practice, highlighting both its successes and its challenges.

A Review of the Ambassador Programme

To better understand the impact and effectiveness of this infrastructuring work, DOAJ initiated a comprehensive review of the AP. This review was designed not only to assess the programme's performance but also to gather insights that could inform the future development of DOAJ as an inclusive knowledge infrastructure. The following sections outline the methodology and key findings of this review.

The review was conducted between January and August 2024 by an outreach working group consisting of three Ambassadors and one of DOAJ's Community Managers. It followed a structured, three-phase approach: 1) documentary data collection; 2) participant data collection; and 3) reporting. An overview of the outcomes was shared publicly on the DOAJ blog (DOAJ 2024).

Data collection combined qualitative and quantitative methods. A survey was used to capture key information and trends regarding Ambassadors' experiences and views of the programme. Focus groups and interviews were designed to explore the motivations, concerns, and perceptions held by Ambassadors, DOAJ core team members, and external stakeholders. Six focus groups were conducted, each

representing specific regions, and fourteen one-on-one interviews were conducted with both internal and external stakeholders.

The findings and outcomes are summarised into four themes. The first theme relates to the regions covered by the programme. As mentioned earlier, the AP was originally created to build local knowledge and skills to increase the number of journals from LMICs. However, as the programme grew organically—often driven by interest or specific needs—regions were incorporated without a clearly defined policy on what countries should be included. As a result, the programme's reach extended beyond LMICs. Moreover, the types of engagement varied considerably across different regions, reflecting differing local needs. For example, in Indonesia, where DOAJ receives a large volume of applications, there is a need to support local journal editors to improve their applications. In contrast, in some Central African countries, there is a greater need to first raise awareness among scholars and journal editors about DOAJ as a resource and index before more strategic, hands-on support can be offered. In other regions, the programme has had a significant structural impact; in South Africa, for instance, the work of an Ambassador led to the DOAJ being accredited by the South African Department of Higher Education and Training (DHET) (Academy of Science of South Africa 2025). However, the review also identified gaps. In the Latin American region, there was a lack of a Portuguese-speaking Ambassador, and additional support was required to support Central African countries.

Feedback from interviewees—particularly from organisations running similar programmes—suggested that DOAJ should set clear expectations and specify regional or country coverage in future calls for Ambassadors. Consequently, a key outcome of the review was DOAJ's decision to redefine the regions covered by the programme. This entailed narrowing the programme's focus exclusively to LMICs and phasing out involvement in regions outside that scope, such as South Korea and Japan. As of 2025, the AP includes active Ambassadors in the following countries and regions: Latin America (Mexico and Argentina), Middle East and North Africa (Algeria), Middle East and Persian Gulf (Egypt), East Africa (Ethiopia), Southern Africa (South Africa), Pakistan, India, Indonesia, and China. Additionally, in 2025, DOAJ recruited new Ambassadors in Brazil and West Africa (Ghana and Nigeria) to enhance regional and

linguistic coverage. An exception to the LMIC focus was also introduced: Ambassadors may be recruited on a time-limited basis to support specific regions outside LMICs where there is an extraordinary need—such as Ukraine, due to the ongoing conflict.

The second theme relates to the definition of the Ambassador role itself. Some stakeholders noted ambiguity in the programme, commenting that the role and its purpose were not entirely clear. This was partly due to the organic development of roles within DOAJ, where Ambassadors were initially involved in reviewing journal applications. Over time, however, the focus of the role has shifted towards engagement and outreach work. In response, a new internal description of the Ambassador role was developed, outlining clearly defined responsibilities. Ambassadors are now responsible for increasing awareness of good OA publishing practices in their regions, educating and engaging their regional communities about DOAJ through events, workshops, and webinars, translating content when necessary and serving as liaisons between DOAJ and local journals—with the aim of increasing the number of high quality, trusted OA journals indexed in DOAJ.

The third theme focused on the structure of the programme itself. Ambassadors had reported a lack of structure, guidance, and communication from DOAJ, making them uncertain about their roles, responsibilities, and the type of support they could expect from DOAJ to carry out their work effectively. As a result, DOAJ has implemented a new structure, including the introduction of three Senior Ambassador roles to oversee Latin America, Africa, and Asia. These Senior Ambassadors were selected from the existing Ambassador cohort, and are responsible for assessing regional needs, managing regular meetings, and coordinating Ambassadors' annual project plans, which outline their priorities and planned activities. This change enabled better alignment with DOAJ's mission and strategy, improved activity tracking, and clearer identification of support needs.

Finally, resources and training emerged as the fourth and final theme. Ambassadors emphasised the need for funding to attend and organise events in their regions. In addition, the survey revealed a lack of awareness regarding existing training materials and resources as well as more support needed to develop new ones. In response, a structured training plan was developed to ensure all Ambassadors had a consistent

level of knowledge. This training gives a thorough overview of DOAJ, internal policies and procedures, with in depth information about criteria and good OA publishing practices.

In sum, the review revealed that building a global and inclusive infrastructure is not a one-time design challenge, but a continuous, reflexive process—one that involves adapting to local needs, supporting the often invisible work of its agents, and making deliberate choices about whose voices and needs are prioritised.

Closing Remarks

In this chapter, we have sought to demonstrate that DOAJ is an open knowledge infrastructure deeply embedded in the global politics of knowledge production and classification. As the history of DOAJ illustrates, building an inclusive knowledge infrastructure is an ongoing process of negotiation, adaptation, and the maintenance of standards that can be met by scholarly journals across the world. This categorical work is inherently political, and as such, it is neither neutral nor straightforward—it involves valorising certain practices while marginalising others. In scholarly publishing, this often reinforces asymmetries in knowledge production and perpetuates epistemic injustices, which disproportionately affects LMICs.

Using the lens of infrastructural inversion, this chapter has also highlighted the often invisible work carried out by DOAJ to navigate the tensions inherent in the politics of classification. The term 'predatory journals' exemplifies this issue. While unethical publishing practices that mislead authors are a genuine concern, labelling or misjudging journals as predatory based on a specific set of (potentially biased) standards—or through the use of blacklists—is unhelpful and can be catastrophic for journals acting in good faith. DOAJ instead views questionable publishing practices as existing on a spectrum, distinguishing between intentionally deceptive journals and those that may be of lower quality due to systemic disadvantages (Krawczyk and Kulczycki 2021).

The AP has demonstrated that infrastructuring inclusivity through a participatory approach is both possible and effective—positioning DOAJ not merely as a gatekeeper of journals, but as a collaborative partner in fostering OA globally. However, findings from the review

of the AP reveal that, while the Programme can effectively counter pervasive epistemic injustices in global knowledge production, it must also navigate the political, ethical, and social complexities inherent in the infrastructure itself. As the criteria for indexing evolve, it is vital for DOAJ to regularly review its processes to ensure they remain aligned with the development of the global scholarly publishing landscape and continue to meet the needs of LMIC regions.

The AP demonstrates that the politics of classification can be navigated not by striving for impossible neutrality, but by adopting a participatory and developmental approach. The goal is not to build a flawless infrastructure, but a resilient and reflexive one that can continuously adapt to the diverse needs of its global community. The review of the AP underscores the importance of community-led organisations investing in their local communities. For a global organisation such as DOAJ, it is essential to continuously monitor—and, when necessary, reassess—its organisational strategies and structures to mitigate epistemic injustices. While DOAJ's team of Managing Editors works across various regions to assess journals, having a dedicated role within the organisation focused on outreach, education, and local community support is invaluable and necessary for a balanced and participatory approach.

We hope this chapter contributes to the literature of the ethnography of knowledge infrastructures by showing how inclusive infrastructure can be built not only through technological design, but through deliberate attention to human relationships, local contexts, and institutional structures. Our empirical examination of the categorical work and the evolution of DOAJ as an inclusive infrastructure offers insights into the pursuit of shaping a more just and equitable global knowledge ecosystem.

Digital Annex

Additional Resource 1: Ambassador Programme's Logic Model. Diagram created by the authors. http://hdl.handle.net/20.500.12434/b9270fae

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9. Paradoxes of Openness: Power, Reciprocity, and the Governance of Scholarly Infrastructures

Katja Mayer[1]

1. Introduction

Scholarly infrastructures are the shared technical, organisational, and governance systems through which knowledge is produced, circulated, evaluated, and preserved. Open scholarly infrastructures form a specific subset of these arrangements: they are infrastructures whose operation is explicitly organised around principles of openness, including transparent governance, community accountability, open standards, and, where possible, non-restrictive forms of access, reuse, and interoperability. In this sense, openness does not refer only to access as an end state, but to the practical and institutional conditions under which knowledge can circulate, be reused, and be collectively stewarded. As articulated in the Principles of Open Scholarly Infrastructure, such infrastructures should be defined not by novelty or efficiency alone, but by their capacity to remain reliable, trustworthy, and accountable to the communities that depend on them (POSI Adopters 2025). In the terms of the UNESCO Recommendation on Open Science, open infrastructures could be both virtual or physical,

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> including major scientific equipment or sets of instruments, knowledge-based resources such as collections, journals and open access publication platforms, repositories, archives and scientific data, current research information systems, open bibliometrics and scientometrics systems for assessing and analysing scientific domains, open computational and data manipulation service infrastructures that enable collaborative and multidisciplinary data analysis and digital infrastructures (UNESCO 2021: 8).

Open science infrastructures are also normatively expected to support a democratising and equity-oriented vision of knowledge circulation (Okune et al. 2019; Bezuidenhout 2025). While they are often relied upon by entire communities and expected to endure beyond individual projects, funding cycles, or technological fashions, much of the labour that sustains them, such as curation, documentation, governance, technical maintenance, is continuous, collective, and typically largely invisible—unless the infrastructure breaks (Bowker and Star 1999; Edwards et al. 2009).

From its early articulations, what is often called open science was never a unified movement in any simple sense, but rather a loose assemblage of policy agendas, advocacy efforts, infrastructural projects, and scholarly reform initiatives. What connected these otherwise diverse strands was a political promise: that publicly funded research should generate benefits for the societies that finance it. Openness was framed as radically enabling, lowering barriers to participation, fostering innovation, and allowing knowledge to circulate into education, policy-making, and economic activity (Fecher and Friesike 2014). This promise was articulated primarily against traditional information intermediaries—commercial publishers who controlled access through intellectual property regimes and subscription models. The implicit assumption was that removing barriers would diffuse benefits across a plurality of actors rather than concentrating them among those already powerful.

It is this assumption that has been unsettled: opening up informational resources means exposing them to the power structures governing the networked information ecosystem. Where the 'open movement' initially constituted itself against exclusive control by publishers and copyright holders (Willinsky 2005), the dominant intermediaries have shifted.

The central issue is no longer only access to scholarly outputs, but who controls the infrastructures through which scholarly communication is organised (Moore 2025). Platform corporations and, more recently, firms developing large-scale artificial intelligence systems now possess the infrastructural capacity, such as compute, integrated data pipelines and technical expertise to exploit open resources at scales and speeds unavailable to other actors. Under these conditions, openness no longer predominantly enables a diffusion of benefits; it risks contributing disproportionately to the power of those best positioned to make use of open resources.

This is the paradox of openness: openness remains a challenge to exclusive control, yet simultaneously becomes an enabler of new concentrations of power (Keller and Tarkowski 2021). Open scholarly infrastructures are caught within this paradox. Repositories, datasets, metadata standards, and benchmarks designed to support collective knowledge production are increasingly mobilised as upstream resources for AI development. The consequences are unevenly distributed: while the labour and costs of maintenance remain anchored in publicly funded institutions, the benefits of large-scale reuse are captured by concentrated private actors. Reciprocity is attenuated; stewardship intensifies without commensurate support. These are not failures of openness, but consequences of openness operating within a political economy of concentrated infrastructural power.

This chapter examines how the paradox of openness unfolds within open scholarly infrastructures under conditions of AI-driven extraction. The analysis is guided by the question: Under what conditions can open scholarly infrastructures be organised and governed to address the power asymmetries that their openness makes possible?

The chapter proceeds as follows. Section 2 situates open scholarly infrastructures within the landscape of knowledge infrastructures, tracing how openness has shifted from access to machine-actionable reuse. Section 3 develops the paradox through three domains—open access publishing, research data infrastructures, and benchmarking—showing how each exposes open resources to asymmetric exploitation. Section 4 interprets these developments through the lenses of power, reciprocity, and infrastructural dependency. The conclusion specifies what the analysis reveals about the contemporary politics of open knowledge infrastructures.

2. Situating Openness in Knowledge Infrastructures

Open scholarly infrastructures are best understood as a specific configuration within the broader landscape of knowledge infrastructures. In science and technology studies, knowledge infrastructures refer to the socio-technical systems through which knowledge is produced, stabilised, circulated, and made authoritative over time (Borgman et al. 2013; Edwards et al. 2009; Bowker et al. 2010; Bowker and Star 1994). They comprise not only technical components—databases, repositories, standards, platforms—but also organisational arrangements, professional practices, legal frameworks, and governance regimes. Knowledge infrastructures are long-term achievements: built incrementally, reliant on sustained coordination and care, and visible primarily when they are stretched, contested, or begin to fail. Crucially, they are political not because they regulate knowledge from the outside, but because they shape the conditions under which knowledge can exist, circulate, and be acted upon.

Within this literature, scholarly infrastructures appear as a subset anchored in academic institutions: publication platforms, repositories, persistent identifier systems, metadata standards, indexing services, benchmark datasets, and the organisations that maintain them. Their purpose is to support scholarly practices—research, teaching, peer review, evaluation—across disciplinary and institutional boundaries (Borgman et al. 2020; POSI Adopters 2025). What distinguishes them is their commitment to durability, reliability, and trust, providing stable conditions for collective knowledge production (Karasti et al. 2016; Star and Bowker 2002; Gregory et al. 2025). As Bowker and Star (1999) have shown, the standards and classifications embedded in such infrastructures are never merely technical; they encode particular values and render alternative arrangements invisible.

The emergence of scholarly infrastructures predates contemporary commitments to open science. Early infrastructures were oriented toward coordination, standardisation, and epistemic authority within scholarly communities, often reinforcing disciplinary boundaries and institutional hierarchies. With the widespread adoption of networked digital technologies from the 1990s onward, questions of openness were increasingly reframed in relation to the affordances of digital

information—its capacity to be copied, distributed, and recombined at scale. Debates on the science commons and knowledge commons emerged in this context, conceptualising scientific knowledge as a shared resource whose public value depended on legal, institutional, and normative protections against enclosure (Hess and Ostrom 2007; Lessig 1999). Scholarship on the digital commons extended this perspective to networked forms of collective production, emphasising peer production, community governance, and open licensing as ways of sustaining shared digital resources (Dulong de Rosnay and Stalder 2020).

Open science entered this landscape initially framed as a problem of access. Early open access initiatives articulated openness as a moral and epistemic imperative: publicly funded research should be publicly available, and barriers to reading scholarly literature should be removed (Chan et al. 2002; Suber 2012). In this phase, openness was largely understood as a property of content, and infrastructures were treated as technical means to deliver access. The political target was clear: commercial publishers and gatekeepers who controlled scholarly communication through intellectual property regimes and subscription models. Openness, in this framing, was a strategy for challenging exclusive control and redistributing the capacity to access knowledge.

Over time, openness became increasingly entangled with questions of reuse. The expansion of digital data production shifted attention from access alone to interoperability, discoverability, and machine-actionability. The FAIR principles—findable, accessible, interoperable, reusable—reframed openness as something that must be actively engineered through standards, metadata, and protocols (Wilkinson et al. 2016). Enabling reuse requires extensive infrastructural labour: metadata production, documentation, curation, and the alignment of heterogeneous epistemic practices across communities (Tempini 2020; Pasquetto et al. 2017). Openness ceased to be a simple attribute of outputs and became an infrastructural achievement dependent on sustained investment and care.

This shift brought the vulnerabilities of openness into sharper focus. Maintaining repositories, updating standards, and ensuring interoperability proved to be resource-intensive and unevenly distributed. The benefits of reuse, meanwhile, were increasingly decoupled from the communities responsible for infrastructural maintenance. Knowledge

infrastructure scholarship has emphasised that such asymmetries are structural features of large-scale infrastructures, where coordination across heterogeneous actors necessarily redistributes labour, authority, and responsibility (Ribes and Bowker 2009; Edwards et al. 2007). Thus, the governance of such infrastructures, when regarded as the ensemble of institutional arrangements, decision-making processes, and coordination practices that sustain shared research infrastructures over time, shows distinctive features, in particular 'community governance', foregrounding the deliberate distribution of authority, responsibility, and stewardship to user and contributor communities in order to secure legitimacy, inclusivity, and long-term operation (Steinhart et al. 2024).[2]

At the same time, the politics of open scholarly infrastructures cannot be understood without attending to the growing role of large information service providers. Over the past two decades, commercial actors have expanded from publishing and indexing into data analytics, research evaluation, workflow management, and infrastructure provision, offering platforms that span the entire knowledge production process (Mirowski 2018; Posada and Chen 2018). This expansion is not merely market concentration; it is a shift in epistemic power. By controlling the technical and organisational conditions under which research is produced, circulated, and evaluated, these providers shape what counts as valuable knowledge and how it can be acted upon. Open scholarly infrastructures are often incorporated selectively into these arrangements, for example as data sources, interoperability layers, or legitimacy anchors, while decision-making authority and value extraction are centralised elsewhere.

It is against this backdrop that open scholarly infrastructure emerged as an explicit object of reflection and governance. The Principles of Open Scholarly Infrastructure articulate openness not as a guarantee of access, but as a condition that must be governed, sustained, and protected over time (Bilder et al. 2015; Neylon 2015; POSI Adopters

2 The 2024 State of Open Infrastructure governance analysis (Steinhart et al. 2024) shows that while community governance structures are now widely adopted and publicly signalled across open scholarly infrastructures, they vary greatly in form, nomenclature, and actual decision making authority, with many bodies remaining advisory rather than fiduciary, governance language often obscuring real power relations, and participation broadly distributed across individuals and institutions despite limited pockets of interlock and concentration.

2025). Recent assessments indicate that many such infrastructures have achieved substantial uptake, operational maturity, and community embedding (Skinner et al. 2025). Yet critical scholarship has highlighted that openness is unevenly experienced: participation depends on institutional capacity, funding regimes, and geopolitical positioning; requirements to share openly often redistribute labour and costs rather than eliminating barriers (Bezuidenhout et al. 2017; Chan et al. 2019).

Recent open science discourse increasingly frames openness in terms of AI-readiness, extending the FAIR principles toward machine-actionable standardisation, interoperability, and large-scale automation (Hosseini et al. 2025; Brewer et al. 2025). This literature emphasises structured metadata, controlled vocabularies, and persistent identifiers as prerequisites for integrating research outputs into data-intensive and AI-driven workflows. Openness is thereby rearticulated not only as access for human reuse, but as infrastructural preparedness for automated processing. This shift carries the risk of reorienting open science toward integration into computational ecosystems where infrastructural power is concentrated—whether this represents capture, adaptation, or a more ambivalent transformation remains an open question.

Situating openness in this way makes it possible to approach contemporary developments not as external disruptions, but as continuous transformations that intensify existing infrastructural tensions. The following section examines how the paradox of openness unfolds when open scholarly infrastructures are exposed to actors whose capacity to exploit openness far exceeds that of the communities who sustain it.

3. The Paradoxes of Openness in Scholarly Infrastructures

The paradox of openness—the insight that openness simultaneously challenges exclusive control and enables new concentrations of power—materialises in multiple ways. Three particular domains of open scholarly infrastructure are chosen to illustrate that openness has not failed, but to explore how it exposes infrastructures to exploitation by actors whose capacity to benefit far exceeds that of the communities

who sustain them.

3.1 Open Access Publishing: From Challenging Publishers to Supplying Platforms

Open-access publishing infrastructures were developed to remove economic barriers to scholarly literature and ensure that publicly funded research is freely accessible. Repositories, open-access journals, persistent identifiers, and indexing services were designed to support citation, discovery, and long-term access within scholarly communities. Openness was oriented toward visibility, accountability, and the circulation of knowledge as a public good—and was articulated explicitly against the subscription models and paywalls maintained by commercial publishers (Suber 2012). Yet, the same openness that dismantled subscription barriers also created conditions under which scholarly content could be recomposed as a scalable input for platform economies.

The politics of access have always been contested. When researchers and advocacy groups pushed for text and data mining (TDM) exceptions in European copyright law, commercial publishers resisted, favouring contractual solutions that would allow them to control and monetise any computational reuse of scholarly content (Jondet 2018; Geiger et al. 2019). The resulting EU Directive on Copyright in the Digital Single Market (2019/790) reflects this tension: while it created a mandatory TDM exception for research organisations, it also permitted rightsholders to opt out of commercial TDM, leaving for-profit miners reliant on the permission of content owners (Geiger et al. 2019). Publishers thus retained significant control over the conditions under which their archives could be computationally exploited.

The irony of this position has become apparent. The same publishers who fought to restrict researchers' TDM rights have since entered into lucrative licensing agreements with AI developers. Taylor and Francis reportedly earned seventy-five million dollars from AI partnerships with Microsoft and other firms; Wiley disclosed forty-four million dollars in revenue from licensing its archives for large-language-model training—with no opt-out offered to authors (Kwon 2024; Battersby 2024). Content that researchers were discouraged from mining is now sold in bulk to train commercial AI systems, while the scholars

who produced it receive nothing. The publishers' earlier insistence on contractual control was not a defence of authors' rights, but a strategy for capturing the value of computational reuse.

The paradox of openness becomes visible here: firstly, open-access content that bypassed publisher paywalls is now harvested as undifferentiated corpora, stripped of epistemic and institutional context, and processed by actors with the infrastructural capacity to operate at industrial scale. The same openness that challenged publisher gatekeeping now supplies platform intermediaries with raw material for extraction. Secondly, even where content remains formally closed, publishers have positioned themselves as intermediaries who profit from AI training while contributing nothing to the infrastructures of open scholarship. The power asymmetry is structural: while the costs of publishing, curating, and maintaining open access infrastructures are borne by authors, libraries, and public institutions, the value generated through large-scale aggregation accrues to actors who contribute nothing to infrastructural maintenance (Mirowski 2018; Posada and Chen 2018).

3.2 Research Data Infrastructures: The Labour of Machine-Readiness

Open data infrastructures and the FAIR principles were introduced to enhance findability, accessibility, interoperability, reuse but also reproducibility of research data across disciplinary boundaries (Wilkinson et al. 2016; Peer et al. 2021). Data repositories, metadata standards, and documentation practices were designed to make data interpretable and reusable beyond their original contexts, presupposing that reuse would occur within scholarly communities with shared norms of attribution and reciprocity. Enabling such reuse not only requires extensive infrastructural labour, but also 'infrastructure literacy' (Gray et al. 2018). As data infrastructures are increasingly oriented toward AI applications, the demands on this labour intensify. AI-readiness refers to the technical preparation of data for ingestion into machine learning pipelines: not only metadata for discovery, but labelling, class balancing, format standardisation, and optimisation for specific model architectures. Critical literature on the intersection of FAIR and AI-readiness has identified a structural gap: FAIR was designed for human-mediated discovery, not for

the machine-actionable precision required by large-scale model training (Neil Majithia et al. 2025; Verhulst et al. 2025). FAIR ensures that data can be found and accessed; it does not ensure that data are labelled, balanced, or technically optimised for machine learning pipelines.

The power asymmetry becomes visible in the distribution of costs for closing this gap. The push to make data 'AI-ready' shifts the labour of technical curation, that is labelling, formatting, contextual stripping, from well-resourced technology firms to under-funded public institutions and research communities (Paullada et al. 2021; Newlands 2021). Data providers are asked to prepare data for forms of reuse that primarily benefit actors with the capacity to exploit machine-readable content at scale. Moreover, making data AI-ready often means removing even more the contextual specificity that makes scientific data meaningful to disciplinary communities, in favour of standardised formats optimised for automated processing (Leonelli 2016).

Here, the paradox of openness lies in the fact that infrastructures designed to enable scholarly reuse increasingly serve industrial-scale content generation, while the labour and costs of readiness remain with under-resourced public institutions. None of this negates the value these infrastructures provide; open data repositories serve researchers, educators, and publics across the world. Yet AI-readiness is also a matter of infrastructural power. Many smaller data infrastructures now find themselves overwhelmed by automated scraping requests, forced to absorb the operational costs of large-scale harvesting while lacking the resources to govern, limit, or benefit from such use. The labour of openness expands; control over its terms does not.

3.3 Open Benchmarking Infrastructures: Evaluation as Competitive Resource

Benchmarks are standardised evaluation infrastructures that measure and compare the performance of computational models against defined tasks and datasets. A benchmark typically comprises a curated dataset, defined metrics, and protocols for reporting results. Benchmarks like ImageNet for computer vision or GLUE for natural language processing have functioned as shared reference points, enabling researchers to compare methods and track progress (Wang et al. 2018; Deng et al. 2009).

In benchmarking infrastructures, openness functions paradoxically: shared evaluation resources meant to enable independent scrutiny become the very means through which proprietary systems gain legitimacy and competitive advantage.

Creating and maintaining such benchmarks requires substantial labour. Datasets must be assembled, cleaned, and annotated through large-scale human labelling. Tasks must capture meaningful capabilities without being trivially solvable. When benchmarks become widely adopted, they require ongoing maintenance: detecting contamination, responding to saturation, and updating tasks as capabilities advance (Orr and Kang 2024; Hardy et al. 2025; Castaño et al. 2024). This work is largely performed within publicly funded research institutions and rarely recognised as the important scholarly infrastructural contribution it represents.

Benchmarks also function as audit infrastructures and, increasingly, as openness proxies. For proprietary large language models for instance, whose architectures, training data, and weights remain undisclosed, benchmark performance often constitutes the only standardised information available about their capabilities. Platforms like Hugging Face have become central here, hosting leaderboards that enable comparison across open and proprietary systems (Fourrier et al. 2025). The paradox of openness is sharp here: evaluation infrastructures created and maintained by open communities become essential for legitimating closed commercial products—yet the labour of producing these benchmarks remains uncompensated by the actors who benefit most.

The asymmetry deepens when benchmarks are absorbed into competitive pipelines. Leaderboard rankings now shape investment decisions, publication outcomes, and market perception (Eriksson et al. 2025). Actors with access to large-scale computational power can iterate faster, optimise more aggressively, and saturate benchmarks more quickly than publicly funded researchers. As benchmarks saturate often within months of release, they lose their capacity to differentiate, prompting continuous cycles of benchmark creation that further advantage well-resourced actors.

Critical scholarship has noted that data-intensive benchmarking especially advantages industry actors, whose computational infrastructure and engineering capacity now vastly exceed academic

resources (Koch and Peterson 2024). The independent audit space contracts even as its importance grows: benchmarks designed for independent evaluation become arenas in which concentrated power determines outcomes (Birhane et al. 2024). While openness enables comparability, comparability under asymmetric conditions reinforces rather than challenges concentrations of epistemic and economic power.

4. Discussion: From Diagnosis to Governance

The previous sections have shown that the paradoxes of openness appear not as a failure of open scholarly infrastructures, but as a consequence of their success under conditions of concentrated infrastructural power. Each case reveals a similar pattern: openness enables access and reuse; actors with asymmetric capacity exploit this openness at scale; the benefits of exploitation accrue elsewhere while the costs of maintenance remain locally anchored. What differs across domains are the specific mechanisms, such as aggregation, extraction, competition, and the particular governance gaps they expose. This diagnosis raises the question that animates the remainder of this chapter: if openness, as currently organised, exposes scholarly infrastructures to power asymmetries that undermine the conditions of their sustainability, then under what conditions might openness be organised differently? Which constraints limit the options available to scholarly communities, and what arrangements might address the asymmetries that openness enables?

I would thus like to highlight three structural conditions that shape the political field within which governance must operate: a temporal mismatch between the rhythms of stewardship and extraction; a pattern of infrastructural dependency that subordinates open scholarly infrastructures to concentrated computational power; and a sovereignty gap that leaves these infrastructures absent from debates about digital autonomy and public infrastructure.

4.1 The Problems of Endurance, Infrastructural Dependency and the Sovereignty Gap

Open scholarly infrastructures are designed for long-term reliability. Repositories, metadata standards, persistent identifiers, and data

services are built to endure beyond individual projects, funding cycles, and careers. Their legitimacy depends on sustained institutional commitment over extended time horizons (Star and Bowker 2002). On the one hand stewardship is slow, cumulative, and anchored in institutions whose temporalities are measured in decades. On the other hand, automated extraction operates on a different temporal register. AI-driven reuse is continuous, fast, and oriented toward rapid iteration: training pipelines ingest data at scale; benchmarks are saturated within months; models are updated in cycles far shorter than the institutional processes that govern scholarly infrastructures. What emerges is a deep asynchronicity between the temporal regimes of open infrastructure maintenance and those of extractive reuse, whereas the labour required to align, coordinate, and sustain institutional temporalities in the face of accelerating demands remains invisible (Felt 2025). The more openness is mobilised for rapid extraction, the more stewardship work is demanded, yet this labour remains tied to slow-moving funding regimes and institutional rhythms that cannot keep pace. Open scholarly infrastructures depend on such care work, while AI-driven extraction intensifies the burden without contributing to its costs. Therefore the stakes of 'infrastructured openness' are better often captured by the term 'endurance' than by 'sustainability'. Sustainability frames the problems as resources and operational continuity. Endurance foregrounds legitimacy and willingness to contribute: whether actors continue to share openly depends on whether infrastructures remain embedded in credible relations of responsibility (Ribes and Finholt 2009; Barry 2020; Henke and Sims 2020; Jackson et al. 2025). When openness functions primarily as an upstream subsidy for extraction—benefits realised quickly elsewhere, costs accumulating locally—the willingness to sustain open contributions erodes (Mayer 2026).

The temporal constraint is compounded by a structural dependency. Contemporary AI development is shaped not only by data availability, but by access to computational power, integrated platforms, and proprietary infrastructures. These resources are highly concentrated among a small number of technology firms, creating dependencies that extend well beyond data reuse to encompass tooling, storage, and the capacity to participate in AI-driven research at all (Ahmed et al. 2023; Whittaker 2021; Widder et al. 2023). Open scholarly infrastructures

occupy an ambivalent position within this configuration. On the one hand, they provide essential inputs, open publications, datasets, benchmarks, that feed AI development. On the other hand, scholarly communities increasingly depend on the infrastructures of large technology providers for the computational resources required to conduct research. Capture thus operates at multiple levels: not only content and data, but personnel, expertise, and infrastructural capacity itself. Scholarly openness becomes entangled in a political economy where public knowledge infrastructures are structurally subordinate to privately controlled computational ecosystems.

This dependency exposes a notable gap in current debates on digital sovereignty. Across Europe and elsewhere, sovereignty discourse has framed digital infrastructure as a matter of strategic autonomy, emphasising data localisation, platform regulation, and investment in public computational capacity. Generally, sovereignty discourses that are not anchored in openness and shared governance risk drifting toward enclosure and fragmentation (Komaitis 2025). Yet, open scholarly infrastructures remain largely absent from these debates. Digital sovereignty is articulated primarily in terms of market logic and economic competitiveness, security, and citizen data protection, not in terms of the public purpose of the epistemic infrastructures through which public knowledge is produced, circulated, and valued (Warso et al. 2025).

This absence is consequential. If open scholarly infrastructures are foundational to contemporary knowledge production and AI-driven innovation, their governance and resourcing are matters of public interest that sovereignty frameworks ought to address. The extractive dynamics traced in this chapter suggest that without deliberate political intervention, open scholarly infrastructures risk functioning as upstream subsidies for concentrated private actors. Sovereignty, in this sense, concerns not only data flows and platform regulation, but the collective capacity to sustain the infrastructures through which knowledge is produced, shared, and acted upon.

4.2 Emerging Arrangements and Their Conditions

These constraints—temporal mismatch, infrastructural dependency, and the sovereignty gap—delimit the space within which governance of openness must operate. They do not foreclose action, but they shape what forms of response become thinkable and practicable. Significant conceptual resources exist across adjacent scholarly and practitioner discourses. From the perspective of open scholarly infrastructure, digital sovereignty is less likely to be located at the state level but in community governance and control over the tools mediating research. The Principles of Open Scholarly Infrastructure address the loss of sovereignty of the scholarly communities precipitated by commercial acquisitions of research platforms, proposing stakeholder governance, open licensing, and 'living wills' mandating asset transfer to community successors should an infrastructure fail (Bilder et al. 2015). Indigenous data sovereignty scholarship offers a parallel critique: Western open science frameworks can reproduce colonial extraction when they disregard the sovereignty of communities whose knowledge is at stake (Kukutai and Taylor 2016; Carroll et al. 2021). The CARE principles—collective benefit, authority to control, responsibility, ethics—insist on the rights of communities to refuse sharing where openness would violate cultural sovereignty.

Expertise on infrastructuring sovereignty treats sovereignty not as legal status but as ongoing technical practice. Musiani (see Chapter 6) argues that sovereignty is 'co-constructed' through situated technical choices: adopting decentralised or federated architectures constitutes 'sovereignty-making' because it prevents concentration of power in central nodes. This perspective—examining how 'humans and organizations build, develop, use, co-opt, and resist digital infrastructures' (Musiani 2022)—opens analytical space for understanding how open scholarly infrastructures might be governed differently. We can distinguish between state sovereignty (control over territory) and popular sovereignty (control by users and communities), a distinction directly applicable to debates over who governs research tools (Couture and Toupin 2019). Recent interventions on university digital sovereignty provide frameworks for how research institutions might deploy regulatory instruments to reclaim control over data generated on commercial platforms (Meiring et al. 2023), while

scholar-led publishing initiatives argue that organisational sovereignty must remain with scientific communities rather than being outsourced to commercial intermediaries (Adema et al. 2017). This concern is reflected in community-led publishing infrastructures such as COPIM and the Open Book Collective, both of which foreground community stewardship, stakeholder accountability, and collective governance as infrastructural conditions for non-commercial open publishing (Hart and Adema 2022; Sanders 2024). This broader orientation is captured by Adema and Moore's notion of 'scaling small', which describes how such infrastructures seek resilience and durability not through concentration or platform-style growth, but through mutual reliance, collaboration, and resource sharing across a bibliodiverse ecosystem (Adema and Moore 2021).

These discourses offer normative orientations and practical models. Several governance arrangements are under consideration: differentiated access regimes distinguishing scholarly reuse from commercial extraction; 'asymmetric interoperability,' where obligations, costs, and benefits of interconnection are unevenly allocated to counter structural power imbalances; further redistributive mechanisms such as levies on AI systems channelling proceeds to knowledge producers (Keller 2025; Blankertz and Windwehr 2025); collective funding reconstituting maintenance as shared responsibility (IOI 2024); data trusts or cooperatives introducing fiduciary obligations into stewardship (Ada Lovelace Institute and UK AI Council 2021); and federated architectures embedding community control into technical design. Drawing on traditions of knowledge commons governance (Hess and Ostrom 2007; Frischmann et al. 2014), these arrangements attempt to reintroduce reciprocity where openness decouples value from the communities sustaining it. However, all of this requires regulatory support that stabilises these governance arrangements by conditioning openness through differentiated access, asymmetric interoperability, and redistributive obligations on commercial AI use.

Amongst many, in particular three conditions appear consequential for their viability: firstly, infrastructures must become visible as sites of governance, not merely technical substrates. Secondly, governance requires institutional capacity—mechanisms for classification,

monitoring and enforcement, which many infrastructures lack. Thirdly, effective contestation may require alliance-building beyond scholarly communities, connecting infrastructure governance to broader mobilisations around digital sovereignty and platform regulation. The question this chapter has posed thus points toward a politics of infrastructure that is only beginning to take shape. The conceptual resources exist; what remains is the slower work of learning how to reconstitute relations of reciprocity adequate to the scale and speed of extraction that openness now enables.

5. Conclusion

This chapter began with the radically enabling promise of openness: that removing barriers to access would democratise knowledge and challenge concentrations of power. The paradox of openness names what this promise obscures. Openness does not operate in a vacuum; it is always situated within existing structures of power. Under conditions of concentrated computational capacity and platform dominance, open resources flow disproportionately to those best positioned to exploit them at scale.

Generative AI renders this dynamic visible with particular clarity. When large language models are trained on the accumulated outputs of open scholarship, such as publications, datasets, annotations, metadata, they do not merely use these resources but transform them into proprietary products that reshape the very conditions of knowledge production. Knowledge becomes automated, extracted from the often slow temporalities of scholarly labour and redeployed through infrastructures that scholarly communities neither control nor, in many cases, comprehend or can compete with. What was contributed under implicit norms of reciprocity is returned as a service, often at a price, by actors with no obligations to the communities that made their systems possible.

This is why the politics of open infrastructures cannot be reduced to questions of sustainability or funding, important as these are. What is at stake is the governance of 'infrastructured openness' itself: the terms under which knowledge circulates, who captures the value it generates,

and whether the communities that produce and maintain open resources retain any capacity to shape their use.

Taken together, the analysis suggests that open scholarly infrastructures can address the power asymmetries enabled by openness only when openness itself becomes an object of governance, structured through reciprocity, differentiated access, and infrastructural self-determination. The analysis presented here might raise uncomfortable questions for communities whose founding commitments were defined against enclosure and institutional control. Addressing the power asymmetries openness enables may require precisely what the discourse of radical openness has historically resisted: governance arrangements that differentiate between forms of access and use; legal frameworks and case law that establish enforceable boundaries; institutional mechanisms capable of monitoring and sanctioning; and political alliances willing to mobilise regulatory instruments in defence of knowledge infrastructures. It may also require redistributive mechanisms, such as taxes, levies or obligations attached to commercial extraction that channel value back to those who sustain the knowledge commons. What emerges is the contours of governed openness: openness that is not unconditional but structured by reciprocal obligations, maintained through enforceable arrangements, attentive to equity in the distribution of capacities, costs, and benefits, and embedded in relations of accountability. Whether such arrangements mark a departure from earlier imaginaries of openness or a necessary maturation of open scholarly infrastructures ultimately depends on how scholarly communities, public institutions, and regulators reconfigure the infrastructures through which openness is made durable.

Yet governance does not need to take on only juridical or regulatory form. Research that considers infrastructuring sovereignty as openness suggests an alternative trajectory: embedding community control into technical architectures themselves through federation, decentralisation, and protocol design that resists concentration (see also Chapter 6 in this book; Tarkowski 2025). Here, governance operates not through external enforcement but through the material configuration of infrastructures: sovereignty as ongoing technical practice rather than legal status. These trajectories are not mutually exclusive; they may prove complementary. What seems clear is that unconditional openness, that is openness

without governance, without redistribution, without infrastructural self-determination, has proved to be openness available for capture. The question that remains is whether scholarly communities can seize the opportunity to govern their infrastructures on their own terms, before those terms are settled elsewhere.

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10. From Data to Display: Infrastructures of Openness in the Making

Lucie Kolb and Lara Kothe

Knowledge sharing is never a neutral act—it requires decisions about what to include, how to structure data and access, and whose perspectives are prioritised. For us, a team of art history, media studies, and digital humanities researchers, this became evident in the development of an open art research database, where sociotechnical challenges and ethical considerations are intertwined. This chapter reflects on the complexities of creating an infrastructure to make our research data public. As a research note, it introduces the ongoing project 'Sharing Knowledge in the Arts' (SKitA) and outlines the preliminary theoretical and methodological work informing our practice.

Our initiative is situated at the Institute of Experimental Design and Media Culture's Critical Media Lab (CML) of the Basel Academy of Art and Design FHNW. The CML's research foregrounds media practices engaging with infrastructures that are integral to collective processes, sociopolitical formations, and the pursuit of common goals. Grounded in trans*feminist, queer, anti-colonial, intersectional, and materialist frameworks, the lab mobilises artistic and computational practices to develop new imaginaries, vocabularies, and methodologies—ones not yet available but necessary for envisioning equitable futures. Its approach to critique emphasises the generative reconfiguration of media and infrastructural systems toward collectivity, and solidarity, aligning with broader struggles against extraction, oppression, and institutional domination.

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In this context, we, art historian Lucie Kolb and design researcher Lara Kothe together with media scholar Stefanie Bräuer, archivists Philipp Messner (until Jan 2025) and Jonas von Lenthe (from Feb 2025), have been conducting the research project 'Sharing Knowledge in the Arts' since September 2023.[1]

Sharing Knowledge in the Arts

Starting from community-organised initiative 'THEswissTHING' (TsT)—an infrastructure for creating connections, sharing knowledge, and collaborating on artistic projects via a Bulletin Board System (BBS) and, from 1996, the internet—SKitA documents the pioneering open digital knowledge practices that emerged in Basel and beyond during the 1990s.

Alongside running a digital infrastructure, TsT also maintained a physical space in Basel, which hosted an event and workshop programme. TsT was linked to the network 'THE THING:' Founded in 1991 in New York, it was a community of artists who initially communicated via BBS and were dedicated to artistic practices of sharing, communicating, and networking. THE THING had various nodes in the US and Europe, including one in Basel.

Although short-lived, TsT provided local artists and theorists in its Basel spaces—St. Johann-Vorstadt (1995) and Bläsiring (1995–1997)—with skills-based digital literacy training and hands-on access to the internet. Through its events, it nurtured net-critical discussions among artists, theorists, and curators, many linked to nettime (1995–ongoing), an email list that encourages debate on the potentials and limits of internet media.

Much of TsT's material has been lost or is inaccessible, making it difficult to critically reflect on its practices and infrastructures today. In response, SKitA first secured data by collecting documentary and archival material on TsT, including promotional material, workshop

1 We are collaborating with digital conservator Dragan Espenschied (Rhizome New Museum New York), digital humanities scholar Lozana Rossenova (TIB Open Science Lab Hannover), and design researcher Adrian Demleitner (University of Bern) to develop the research database. The broader team also includes artist-researcher Eva Weinmayr, who contributes a complementary reflection on classification in search interfaces, taking library catalogues as an example.

information, and curated text collections.[2] Secondly, we conducted filmed interviews to contextualise the data via oral history with artists, curators, and theorists who were involved in TsT or have participated in related activities or projects.[3] In the third phase, we have been creating an open database using the open-source tool Wikibase, a collection of extensions for the open-source software MediaWiki to make our research data accessible. Following the creation of a project-specific ontology for our Wikibase database and the integration of the processed material, we are now developing the visual interface of the database. This process is informed by a close reading of the oral history interviews and archival material through the lens of our central research question: What was the understanding of openness in TsT? How did it manifest in its infrastructure, pedagogy, and publishing?

In this process, the database is not simply a means to an end to secure and share research data on practices around TsT in Basel, but a research object in its own right. Inspired by the practices we investigate, we ask: How can we translate social and ethical community-based notions of sharing and open access into the publication of research data?

This research note zooms into the creation phase of the database's visual representation and seeks to outline preliminary answers for the translation of those notions of sharing and open access into an open research database.

Open Research Databases

In humanities research projects, research databases serve as a crucial resource for scholars to access and analyse materials.[4] Databases

2 SKitA includes the archive of Barbara Strebel, along with material from interview partners and collected material from Annette Schindler, Stella Händler, and Reinhard Storz.

3 As of now, the research includes interviews with Reinhard Storz (xcult.org, TsT), Barbara Strebel (TsT), Valentin Spiess (iart), Studer/van den Berg, Annette Schindler (plug.in), Yvonne Volkart (Old Boys Network OBN), Enrique Fontanilles (Medialabor Ø.1), Catherine Walthard (HyperWerk), and Felix Stalder (nettime, TsT).

4 The Swiss research landscape hosts a number of open research databases which were developed in various university contexts and often organised by disciplines. As of now, there is no national or international database provider for practice-based research in art and design. Moreover, research in art and design is considered part of humanities research and thus integrated in its infrastructures. DaSCH is the major research database in Switzerland for the humanities. Developed by Basel

provide a structured, searchable collection of information. In the context of open science (OS), a movement associated with harnessing digital possibilities to make research more widely available, faster, cheaper, and more efficient, databases have become increasingly public (Adema and Hall 2013: 147). Openness is the foundation of good research and data management practice, promoting participation in scientific progress for everyone, regardless of cultural, social, or geographic background, helping to bring about a democratisation of research (UNESCO 2023). The conceptual and technological framework of 'open' data management has been increasingly standardised over the last ten years.[5] One influential technical best practice standard is the 'FAIR Guiding Principles for Scientific Data Management and Stewardship,' introduced in the British scientific journal *Nature* in 2016, and which have since been widely adapted (Wilkinson et al. 2016). The acronym FAIR stands for: findable, accessible, interoperable, and reusable. FAIR proposes that scientific data have four key components: it should be easily located (findable); readily available (accessible), with both metadata and data retrievable by humans and computers alike; data should be compatible with multiple types of software and devices (interoperable); and, capable of being used again for future research (reusable), thereby promoting more effective and collaborative research practices.

Substantial criticism has been levelled at the foregrounding of technological solutions for achieving open data management inherent in the FAIR framework. From feminist and anti-colonial perspectives, it has been argued that FAIR's understanding of openness overlooks the social and political factors crucial in determining how knowledge can become accessible (D'Ignazio and Klein 2020; Carroll et al. 2020; Chan 2014). While the principles focus on the properties of data and materials that facilitate data exchange and thus on technical aspects, ethical aspects and historical contexts of data production are largely ignored (Carroll et al. 2020). This oversight leads to several issues, including the potential misuse of data, a lack of accountability for sources and methods of data

University, DaSCH provides access to research data collected or generated in a research process and shared with others for reuse. Our project will eventually be included in DaSCH.

5 In the Swiss context, the ORD Strategy Council was formed as a national entity to coordinate the standardisation process together with the stakeholders: https://openresearchdata.swiss

collection, and an incomplete understanding of the societal impact of data practices (Staunton et al. 2021).

Given the prevailing power structures in science, OS is subjected to particularly rigorous scrutiny through the lens of anti-colonial theories. At the most critical end of the spectrum, it is even seen as embodying a Western perspective that may inadvertently perpetuate colonial practices (Dutta et al. 2021). This critique suggests that OS may reinforce power imbalances and overlook non-Western epistemologies and methodologies. For example, the Global Indigenous Data Alliance (GIDA) has challenged the FAIR principles' strong emphasis on making research data available, noting that this framing neglects to ask why and to whom data should be made available and how that availability benefits the communities from which the data originates (GIDA 2019). In response, GIDA, together with a group within the Research Data Alliance, developed an alternative yet complementary set of principles called CARE: *Collective Benefit, Authority to Control, Responsibility,* and *Ethics* (GIDA 2019). Whereas FAIR prioritises end-users by centring the availability and technical accessibility of data, CARE foregrounds the rights and interests of communities of origin—specifically Indigenous peoples. CARE aims to ensure that the use of data aligns with those communities' values, supports their self-determination, and redistributes authority over their data circulation. Although our project does not involve Indigenous data or governance, it resonates with and extends the impetus of CARE by insisting that openness be understood as an ethical, contextual, and relational practice rather than a purely technical one. Where CARE focuses on Indigenous sovereignty and community control of data, our framework applies similar concerns to artistic research and archival practices. In doing so, we contribute to a broader rethinking of openness—alongside initiatives such as CARE—that challenges technocentric paradigms and foregrounds responsibility, situatedness, and care in the design of research infrastructures.

Setting the Stage

Beyond providing access to documentary and archival material, creating contextual metadata and interviews, we developed a research database that takes up the sharing practices of the 1990s and re-examines their

articulation today in light of the feminist critique of OS outlined above. We conceive of the database not simply as a repository but as research in its own right—an artistic 'small data' experiment in feminist knowledge production. Drawing on Liu's approach (Liu 2021), we understand this experiment as contributing through practice to the ongoing articulation, critique, and experimentation around what 'open' means.

Starting from a critique of the narrow view of openness as merely providing technical conditions for efficient access, our project develops concrete infrastructures that embody and support a broader conception of openness informed by feminist approaches to digital technologies. For us, infrastructuring openness is a recursive and ongoing process that involves three interrelated components: contextualisation, reflexivity, and the design of open-ended systems. These components are not only technical but also deeply political, shaping how knowledge is accessed, framed, and reused.

As we develop our database with a focus on TsT's sharing practices, we first need to outline some key aspects to set the stage for discussing how we visually represent our research data: What were the social and ethical notions of sharing inherent to those practices? TsT centred on a form of knowledge sharing that emphasised access: to digital infrastructures and means of production, computers, modems, servers, the BBS and the internet, and to a network engaged in critical media discourse on knowledge sharing (Bräuer 2025). Drawing on DIY self-publishing strategies, such an understanding of knowledge production had the political aim to empower those using the infrastructure to see themselves not just as recipients of messages or posts, but as active authors. TsT established a media space that questioned who could speak and mapped what lay outside highly conventional media. It was about creating new publics by building and maintaining collective infrastructures that fostered awareness of transparency, power imbalances, and the subjection of media infrastructures, while offering agency through self-organisation. These publics were less about aggregating people than about creating community through collective action. Knowledge sharing thus went beyond sharing content and shaped the framework of production by developing and maintaining infrastructures, creating access, providing means, and generating an audience.

TsT's open, transversal, and non-outcome-related approach to

knowledge sharing came with its share of conflict, which at least in part reflected the chaos and anarchy of new media at a time when it was still unclear how media would be used artistically, politically, and commercially. In this sense, considering openness means embracing divergent perspectives. Mapping the multiple perspectives and positions within the heterogeneous community in our database requires foregrounding the contexts in which data emerged: where they came from, how they were produced or collected, and under what conditions.

This shift calls for moving away from viewing data as isolated objects and instead recognising them as relational and processual. It also involves acknowledging what data is present and what is missing, where gaps or biases may exist. Just as important is situating our research itself, i.e., reflecting on the research team's narrative lens and position. Rather than claiming neutrality, we draw on the concept of *Situated Knowledges* (Haraway 1988), recognising that all research is embedded in social, historical, and institutional contexts.

By embracing this situatedness, we critically engage with the infrastructures we analyse. This includes visualising and disclosing our methodological choices, institutional affiliations, and positionalities—not as a neutral backdrop, but as integral to the research process. We view this act of disclosure as a feminist practice: one that makes visible the roles of funding, institutions, technologies, and individuals in shaping outcomes. Making these dynamics (decisions, priorities, hierarchies) legible fosters accountability. It lays the groundwork for more equitable forms of knowledge sharing by equipping users with insight into the structures that mediate access. In doing so, it opens space for diverse, even conflicting, forms of inquiry to coexist.

Contextualising through LOD, Metadata, and Ontology

In our implementation of Wikibase, beyond embedding context through descriptive metadata, we contextualise the material through the structure of the database, which is built in a Resource Description Framework (RDF) graph model. Wikibase uses 'triples' (subject-predicate-object) to represent semantic relationships at different levels, allowing an articulation of the processes and conditions under which data was generated. We chose Wikibase because it provides an open,

flexible, and community-supported infrastructure for linked data, while remaining adaptable to small-scale, experimental projects. Unlike many proprietary or closed systems, it allows us to foreground provenance and relationality rather than enforcing rigid schemas, which is crucial for our artistic and feminist approach to data. This approach draws on principles of archiving, where documenting the circumstances of record creation is essential to enable future interpretation. One question guiding our work was how to adapt these archival methodologies for the management of research data: how can the context of origin be effectively articulated within a database?

To address this, we employed unique identifiers, standardised ontologies, and controlled vocabularies, thereby producing Linked Open Data (LOD). Wikibase supports this structure, allowing us to model the relationships and provenance of data while preserving its contextual integrity. Linked data also accommodates multiplicity. For instance, by capturing the various spellings of the project name 'TsT' used by different contributors, it reflects the diversity within the community itself (Messner 2025).

SKitA developed a custom data model combining CIDOC CRM, a conceptual reference model for representing cultural heritage events and their contexts, with Records in Contexts (RiC) for traditional archival structures. This hybrid ontology was implemented in Wikibase, enabling structured, machine-readable metadata. However, due to technical constraints, the Wikibase instance couldn't be made permanently public. To contribute to the LOD ecosystem, entities such as persons and organisations were created or enriched in Wikidata, ensuring openness, interoperability, and collaborative enhancement of the data beyond the project scope.

The next step is translating this structured contextualisation into the visual domain. If infrastructuring openness begins with LOD, ontology, and metadata, then visualisation is where those frameworks become legible, interpretive, and contestable. It is through visual interfaces that ambiguity can surface, absences can be acknowledged, and positionalities made visible. Our visualisation is not a passive display but an active interpretative layer, one that embodies our critique of openness by making structures transparent, surfacing epistemic standpoints, and inviting alternative engagements with the data.

Data Visualisation: Representation and Interpretation

Data visualisation is the translation of data into visual formats. This serves as a gateway for interacting with data, thereby materialising an access point for users. Data visualisation in the digital humanities depends on conventional frameworks and technologies to allow for data-centred research. Often standardised models designed primarily for statistical display (Drucker 2011), such tools (e.g. Gephi, nodegoat) rely on abstractions and simplifications to serve their purpose. Generic tools cannot capture the unique perspectives and research questions of individual projects. This is especially true when these questions address gaps, ambiguities, multi-perspectives, one-sided connections, memories, and hidden aspects like undocumented labour—in short, all that resists conventional translation into data and static visualisations of relationships, such as solid lines between two nodes.

A common standardised model is the network knowledge graph, where data appears as circular nodes connected by solid lines to reveal relationships and generate new insights, often used in humanities research on business, migration, or correspondence networks. Each node's position is determined by applying fixed layout algorithms. This process aims to produce a seemingly clear visualisation that allows the viewer to distinguish individual nodes and observe interrelated patterns within the dataset (Mertel n.d.). However, when applied uncritically to most graph-drawing algorithms, the desire to display semantic links—and as many of them as possible at once to address different research questions—leads to various visualisation issues, including the so-called 'hairball' phenomenon, which is often caused using technically accurate distance representations (Peixoto 2024). Here, the network datasets connections are so complex that visualisation produces a 'hairball' (Mertel n.d.; van Geenen and Wieringa 2020: 152). There are efforts to address this issue. One approach is to focus on specific aspects of the relationships (e.g., graph filtering) or to simplify the semantic connections (e.g., group nodes) (Williams 2023). But this requires visualisation experts, often overlooked because of budget constraints.

According to Data Feminism, data visualisations as knowledge infrastructures reveal data-fact knowledge by making data accessible visually, constructing specific narratives, and facilitating insights

(D'Ignazio and Klein 2016). This understanding of data visualisation is rooted in visual culture, where data visualisations are conceived as absolute, accurate, and neutral representations that allow for one singular understanding (Tufte 1990). But as with data itself, visualisations cannot be seen as objective translations of 'raw data' (Gitelman 2013). Data Feminism visualisation practices 'challenge claims of objectivity, neutrality, and universalism, emphasising instead how knowledge is always constructed within the context of a specific subject position' and propose six concrete principles, namely 'Rethink Binaries, Embrace Pluralism, Examine Power and Aspire to Empowerment, Consider Context, Legitimize Embodiment and Affect, and Make Labor Visible' (D'Ignazio and Klein 2016: 2–5). D'Ignazio and Klein push against seeing visualisations as objective representations, arguing instead that they should be seen as complex constructs shaped by representation choices and interpretation processes.

Choices in representation, because representations are as Stuart Hall stated, an 'active work of selecting and presenting, of structuring and shaping: not merely the transmitting of an already-existing meaning, but the more active labour of making things mean' (Hall 1982: 60). They can be seen as a practice where power negotiations take place within decision-making frameworks, as activities such as producing, introducing, performing, and exhibiting come together and are often carried out by the person(s) creating the visualisations. In research projects, however, multiple authorship positions come into play, including those who create the underlying dataset, those who convert it into a research database, and those who visualise the underlying ontology, each bringing their own situated knowledge. The steps in this process are often not carried out in an interdisciplinary team, but independently and with standardised tools, which can lead to a lack of coherence, critical reflection, and disclosure of one's own position in the individual phases.

Processes of interpretation, because visualisations are a distinct form of knowledge production, thereby going beyond the mere depiction of something: They have the potential to facilitate the discovery of new connections and narratives as a means of knowledge. By allowing viewers to 'see' in a particular manner, they contribute to forming one's reality, thereby assuming a central role in the cognitive process. Part of

this process is the viewer and visualisation interplay: it involves a process of 'reading' and performative interpretation that leads to an individual understanding of the visualisation (Drucker 2013). When a viewer encounters a visualisation, they decipher its content by performing an act of interpretation that is influenced by their individual perspective, cultural background, and experiences. This act involves questioning, linking, and recontextualising the visual information, leading to new knowledge. The process, in turn, can be understood as performative, as the viewer transforms the visualisation from a static representation into an active site of meaning-making, where they play a crucial role in shaping its significance. Meaning is thus not given in a visualisation but depends on the engagement of the viewer, reflecting the situational nature of visualisations and making them sites of interventions.

Alternative Imaginaries

In the following, we discuss alternative imaginaries that approach visualisation as an active site of meaning-making shaped by representation choices and interpretation processes, which resist attempts at hierarchisation, embrace the coexistence of multiple narratives, and disrupt the ways conventional tools often reinforce conventional knowledge. These aspects serve as reference points for implementing our own data visualisations. We aim to identify both what they offer—strategies for non-hierarchical complexity or context—and their limits, especially with regard to openness, transparency, and ambiguity. Rather than focusing on research databases in the literal sense, we deliberately considered examples from archives, libraries, and related infrastructures. This decision reflects the nature of our own data context and the knowledge practices in which we are engaged.

Materialarchiv

The first example is the Materialarchiv, which is not a research data archive in the traditional sense, but an archive that resonates with our own work.

The Materialarchiv is a collection of different materials and their methods of processing and use. The data visualisation was designed by

the agency Astrom/Zimmer and Tereszkiewicz in 2023. Its relevance lies in the way it treats material knowledge, in its exploratory interface design, and in the way it structures access and relationships between artefacts.

A closer look at the interface reveals that the individual properties of the material are semantically linked to other components such as processes, reference objects, events, etc. No hierarchy is imposed on these elements. The viewer can decide which component best suits their interests when approaching the material. Free, intuitive browsing facilitates open knowledge exchange. As in our case, the database of the Materialarchiv draws on an RDF graph model to connect data, thus enabling a shift in the interest perspective and providing news ways to explore the material world. This approach emphasises interconnectedness and enables exploration from multiple perspectives, revealing material complexity.

However, certain limitations become apparent from a data feminist perspective. For instance, the section 'Relevanz' (relevance) lacks transparency about who determines relevance, raising questions of authority. While data contributors are listed in the metadata, attribution is limited to general institutional labels (e.g., 'ETHZ') or initials (e.g., 'KB'), without clarifying who it refers to. This requires additional research in the 'Impressum' section to understand the context and responsibility. Although the interface is rich and non-hierarchical, it can sometimes be disorientating, particularly for nontechnical users. The multiple entry points and navigation paths require significant effort to comprehend and can leave users with a sense of 'being lost' in the complex web of relationships. Additionally, the lack of a participatory element is noticeable: users cannot contribute to the network, annotate existing metadata, or challenge categorisations. This limits engagement and the potential for a more inclusive, contested knowledge space. While users can create their own collections, these cannot be made visible to others through the interface, which further restricts opportunities for collaborative knowledge building and public dialogue.

Infrastructural Manœuvres in the Library

Another example is the interface of the library catalogue of the Rietveld Academie and Sandberg Instituut in Amsterdam, which experiments

with the library's technical data infrastructure through annotations. This interface is particularly interesting to us because it enables collaborative knowledge production by allowing users to contribute their own comments and corrections.

Infrastructural Manœuvres in the Library is a collective project that reexamines the components of the library and rethinks their interconnections. At the heart of this is an interface that makes the library catalogue writable. Viewers can interact with the catalogue in four modes: ADD, CHANGE, REMOVE, and BUT. While the first three correspond to familiar editing actions BUT introduces a space for qualification or dissent—allowing users to register contradictions, tensions, or alternative readings without overwriting existing entries. Rather than generating preformatted annotations, viewers can individually edit, contribute to, and criticise the existing categories.

This approach de-centres expert authority, fostering inclusivity, opening space for alternative or even conflicting classifications, and in the process questioning traditional hierarchical structures. It highlights issues of selection, classification systems, and authorship, while revealing the nuances, uncertainties, and grey areas within these processes. By enabling ambiguity instead of forcing simplification, the system offers multiple perspectives on the same artifact. This fosters responsibility and community accountability through ongoing dialogue around the displayed data. Through collective stewardship, alternative knowledge infrastructures are created. Despite this critical intervention, limitations remain. Meaningful participation requires time, motivation, and familiarity with the system, which can act as a barrier, especially for users outside of academic or technical contexts. Users engaging in critique, correction and classification are doing so without institutional recognition, financial compensation, or credit. This raises questions about the ethics of relying on unpaid volunteer work. While the ability to edit categories appears to disrupt hierarchical structures, the underlying metadata schema seems to remain intact and unquestioned, thereby limiting the depth of structural change. Furthermore, the process by which annotations are acknowledged and integrated into the system is not transparent to users of the interface, which may undermine contributors' sense of agency and impact.

The Sound of Water

In terms of setting, the last example, the Sound of Water, is closest to ours, as it focuses on communicating a database for a research project involving cultural heritage data. An interesting aspect is the poetic approach, which prioritises exploration over a single narrative. Rather than using standardised data visualisation, the data is presented as storytelling—through methods such as audio recordings—which is designed to evoke certain emotions. This interface approach uses artistic means, such as sound and image patterns, to represent data, offering an alternative to conventional data visualisations.

The Sound of Water is a microsite created by Mitchell Whitelaw and ecologist Dr Skye Wassens. This initiative tells the story of the NapNap Swamp in Australia, located on the land of the Nari Nari people. Whitelaw is an academic, writer, and data visualisation expert known for his work in designing 'generous interfaces.' These interfaces challenge the traditional approach that requires viewers to get information through a single query. Instead, Whitelaw creates visualisations that offer multiple pathways, encouraging viewers to explore, interpret, and uncover relationships and structures within the translated data, particularly in cultural heritage collections. He has designed the microsite to provide a poetic experience beyond the traditional dissemination of scientific research data. Using audio recordings, water data, and images collected over nine days in 2020, the project translates 'hard' data facts as well as feelings to create a vivid visualisation of life in the swamp from a dry to a wet period. Controlled environmental flows cause the wetland to change, and this change has been captured through interactive false-colour spectrograms that reveal the different rhythms. The spectrogram shows daylight hours dominated by birds as pink and orange areas, the sounds of crickets as solid horizontal bands, and rainy, windy weather as blue areas. Frog calls are represented by bright areas, mostly at night, against a black background, with the presence of the endangered Southern Bell Frog being of particular interest (Whitelaw et al. 2024). This intervention uses visual storytelling to ask how environmental data can reveal, rather than hide, the human connection to the environment.

Nevertheless, some issues remain unresolved. Although further details can be found in a separate academic paper (cf. Whitelaw et al., 2024), the selection process for the audio recordings prominently

featured in the interface is not clearly disclosed on the website, and users must look for the context elsewhere. While the project acknowledges the Wiradjuri, Nari Nari, and Muthi Muthi as the traditional caretakers of the Lowbidgee wetlands, there is no clear process for Indigenous communities to determine whether and how their knowledge and cultural perspectives are represented, discussed, or reused in the project. This omission highlights the importance of prioritising Indigenous data sovereignty, in line with principles such as the CARE framework, to ensure that the community retains control over decisions regarding interpretation and presentation. The website lists frontend libraries such as AngularJS, Scrollama, Howler.js, and Flickity, but at first glance it does not seem to disclose which training algorithm was used for bird song recognition and whether parts of the soundscape have been omitted or filtered out, which would be a key methodological detail. This lack of transparency carries the risk of reproducing technocratic authority. Finally, while the project relies heavily on auditory interaction, it does not appear to offer alternative modalities, such as transcripts or textual summaries. This could be a barrier for users with hearing impairments.

Learning from Others

A key challenge in our work within SKitA is developing a data visualisation that reflects the ambiguities and gaps in the RDF dataset, rather than presenting a rigid, oversimplified view. Instead of constructing dominant narratives, we aim to visualise the complexity of the infrastructural practices at the centre of our work and reflect the relationships represented in our dataset.

The Materialarchiv's approach to LOD offers a valuable reference, using recursive and polyphonic visual strategies that avoid highlighting a single interpretation. Relationships shift based on the user's interactions, emphasising the contextual nature of the material. Similarly, Infrastructural Manœuvres reframes infrastructure as a participatory space—moving beyond functional cataloguing toward collaborative knowledge production and collective exploration, encouraging users to engage in distribution practices that foster a more inclusive exchange of knowledge. We also draw inspiration from The Sound of Water, where sound visualisation, linked to source audio, invites users to engage with more-than-human ecologies, encouraging interpretive openness.

Developing our own interface requires integrating multisensory and cross-modal elements—such as oral history filmed interviews—to address data gaps and ambiguities and foster immersive engagement. To reflect the networked nature, the interface must offer non-linear exploration and multiple points of entry. Just as importantly, it should support collaboration by enabling comments, suggestions, and critique, with transparent moderation and fair recognition of contributions.

We make decisions around LOD, metadata, and prototype versioning visible, fostering reflexivity and accountability. By addressing questions of sovereignty, transparency, labour, and access, we aim to create a just, community-oriented interface that supports inclusive, ongoing knowledge exchange.

Thus, our interpretation of openness requires a visual interface that represents the underlying practices adequately—one that reveals its design choices and assumptions, and the origin of the data it represents. It is crucial, in our view, that openness allows space for ambiguity, complexity, and contradictions—as well as the limits of what can or should be visualised. We do not aim to implement a fully-fledged system that makes complex ontologies entirely visible and workable, but rather to prototype selective functions—such as exposing design choices, documenting provenance, and representing multiple or contested relations—that serve as proofs of concept. In this way, the interface itself becomes an experiment in reflexivity, foregrounding openness as an ongoing, situated practice rather than a finished technical solution.

Closing Preliminary Thoughts

Knowledge infrastructures are not passive pathways but contested, conflictual spaces shaped by access and negotiation. Attending to openness, then, involves exploring how careful and considered infrastructure design can facilitate openness without reproducing dominant norms, and instead enabling the exploration of alternative imaginaries.

Through our work, we have come to understand openness not merely as a question of dissemination or digital accessibility, but as a critical and contextual practice that encourages reflection on how, by whom, and under what conditions knowledge is shared. Openness therefore

is not just a technical feature but a political and ethical commitment for everyone involved.

This requires a focus on interdisciplinary collaboration as a methodological principle that facilitates dialogue between different epistemologies, practices, and values. Importantly, we have learned to consider data, infrastructure, and collaboration in relation to each other: we must view them not as separate components, but as intertwined and mutually dependent. Accordingly, we can redefine the database and its visualisation as an evolving, collective process—a 'living system' that grows through critical engagement, participation, and care, rather than as a finished product or final repository.

With this understanding, openness becomes a mode of resisting closure, disrupting extractive knowledge practices, and building more just and inclusive forms of exchange. This ongoing process requires us to rethink not only how data is accessible, but to reconsider the infrastructures through which knowledge is created, communicated, and shared, guided by questions of justice, accountability, and community.

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IV. COMMUNITY-DRIVEN INFRASTRUCTURES OF CARE AND REPAIR

11. Beyond the Digital Divide: Data Governance and Indigenous Sovereignty in Andean Potato Conservation

Julio Sebastián Zárate Vásquez and Jason A. Delborne

1. Introduction

After meeting Ana during the workshop at Hermilio Valdizan University in Huánuco, I met her again to visit her village early at dawn. She was with her son, and we shared a vehicle together with a workshop facilitator that trained students like Ana how to use their phones to upload images of potatoes. Since Ana mentioned that her family has diverse potatoes and, as a student, she was thus committed to writing her dissertation based on the data collected from her village, she seemed motivated enough to use her phone to upload potato data beyond the workshop. After sharing a meal with her family, who mostly spoke Quechua, Ana showed us her potato plot. Just before meeting her in the field, I was interviewing her aunt-in-law in the kitchen. She often looked down when we spoke and, in some instances, she was non-responsive. Later, after Ana brought back a sack of potatoes, I met her brother-in-law, who mentioned that he was frustrated about the lack of education that the older women in his family had received decades ago. Even after attending the workshop the prior day, it took Ana a while to take

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pictures and add agronomic and morphologic data to the app. Her aunt-in-law first observed, but later joined her to classify their potatoes. Her expression changed; she was enjoying naming potatoes and recalling names in Quechua and their meaning. This pattern—enjoyment in the practice of sorting and naming potatoes, coupled with the difficulty of using phones to record data—was not unique to Ana's aunt-in-law. Other Andean farmers who participated in citizen science workshops similarly enjoyed sorting potatoes but struggled to use their phones to do it. Ana's experience illustrates a persistent tension in citizen science initiatives: whilst farmers and their families possess deep knowledge of agrobiodiversity and often enjoy the cultural practice of naming and classifying Andean potatoes, the technological infrastructure designed to capture this knowledge can create barriers rather than facilitate meaningful user participation. This reveals a disconnect between the design of data collection platforms and the lived realities of users in rural Andean communities. Understanding this disconnect requires examining how data platforms like Wiki Papa and VarScout mediate between Andean knowledge and standardised agrobiodiversity data collection protocols.

This chapter examines the processes of potato agrobiodiversity curation and user feedback integration within the data platforms Wiki Papa and VarScout. Wiki Papa functions as a curated website hosting records of Andean potato varieties, encompassing agronomic, geographical, and gastronomic traits. App developers and agrobiodiversity researchers act as data curators of this information. In parallel, VarScout, a smartphone application, enables its users to collect on-the-ground data—such as local names, colour, and yield—directly from potato fields and rural farms. VarScout users include custodian potato farmers, rural extension workers, and students based in rural regions. The data collected via VarScout is subsequently uploaded to Wiki Papa, forming part of a unified citizen science project led by the International Potato Centre (CIP, Spanish) dedicated to monitoring potato agrobiodiversity.

Stakeholders across the potato data value chain—including data curators, app developers, and agrobiodiversity researchers—seek to support farmers' livelihoods. Yet, as scholarship on information infrastructures demonstrates, the design of data systems inevitably

embeds social assumptions and power relations—often rendering them invisible or taken for granted (Bowker 1994; Bowker and Star 1999; Star and Bowker 2006). Potato data platforms similarly embody classificatory choices and institutional logics that structure what becomes legible and actionable as data. For instance, data practices within the Wiki Papa platform tend to favour Western standards, such as agronomic and morphological descriptors used to classify agrobiodiversity in catalogues. Digital literacy, skills, and capacity in rural Peru remain limited (MINEDU 2022; CEPLAN 2023; Rodríguez 2022; Libaque 2023). As a result, users based in rural regions that have limited digital skills may struggle to understand how their data is being used, as well as the expectations surrounding their involvement in data collection.

Given these dynamics, it is important to consider how data governance principles—specifically FAIR and CARE—within Wiki Papa and VarScout are shaped by socio-technical infrastructures and design choices (Bijker, Hughes, and Pinch 2012). FAIR principles for data management (Findable, Accessible, Interoperable, Reusable) and CARE principles for data governance (Collective benefit, Authority to control, Responsibility, Ethics), are generally discussed together in deliberations about open access, community rights, and ethical considerations of data (Carroll et al. 2020; Wilkinson et al. 2016). Whilst Wiki Papa and VarScout were designed to promote accessibility and inclusivity, they nonetheless struggle to comply fully with FAIR and CARE. These principles address ethical concerns such as what is being digitised and why, as well as how data is categorised (Chigwada and Ngulube 2025). Such concerns are situated in a broader context in which Latin American rural communities, particularly women, face persistent obstacles, including limited access to information and communication technologies (Rotondi et al. 2020).

The next section explores the challenges of complying with FAIR and CARE in contexts where a strong digital divide persists—manifested not only in limited access to technology but also in the absence of digital skills. Although previous studies on rural Peru (MINEDU 2022; Rodríguez 2022) have focused on the digital divide to inform policy, the literature has not yet considered how these constraints limit compliance with data governance principles when rural communities engage in data stewardship. To address the ethical concerns surrounding their

involvement in digital platforms, it is necessary to create spaces for deliberation about data governance as well as users' experiences of these platforms.

2. Theoretical Framework: Digital Divide, Data Sovereignty and Datafication

As a consequence of rising inequalities in the digital economy, organisations, scholars, and policy-makers have brought to the public agenda the idea of reducing the digital divide, understood as the gap between people who have access to information and communication technology (ICT) and those who do not (Lythreatis et al. 2022). The digital divide is a key issue for social justice (Rogers 2016), since digital gaps can either restrict or enhance citizens' social and financial capital as well as their participation in society (Ragnedda 2017). Closing digital gaps by providing training and adequate infrastructure could reduce inequalities. Nevertheless, programmes such as One Laptop per Child in Peru demonstrate that inequalities persisted even after training and increased access to technology (Cueto et al. 2024).

The Peruvian Ministry of Education (MINEDU) developed a policy report aiming to close digital gaps in rural areas by implementing policies that provide 'equal access to a comprehensive education that allows for the full development of human capacities in society' (MINEDU 2022). In this document, the digital divide is defined as the 'distance between people, communities, states, countries, etc., who use ICTs as a routine part of their daily lives, and those who do not have access to them, or do not know how to use them' (MINEDU 2022). This definition highlights both the access gap in relation to equipment and digital educational materials, and the usage gap involving digital skills and capacities.

For the purposes of this chapter, we reviewed the literature that examines how the digital divide interacts with rural communities and Indigenous peoples in Latin America. Rotondi et al. (2020) highlight the persistence of gender gaps, providing evidence of a first-level digital gender divide related to access to ICT rather than the skills required to leverage their potential. González and Martínez (2023) point out that, although Latin America as a region has the highest proportion of Indigenous population globally, Indigenous Peoples experience a

digital ethnic divide, as the development of digital infrastructure has prioritised urban areas. Ávila (2023) shows that the digital divide disproportionately affects Indigenous Peoples, who face limited access to digital services and cultural and linguistic barriers that prevent them from fully benefiting from digital technologies.

In Peru, studies have examined the development and implementation of digital tools for learning Indigenous languages (Yahuarcani 2020; 2021), the use of WhatsApp as a mobile learning resource (Escobar-Mamami and Gómez-Arteta 2020), and the tensions between Indigenous communities and the implementation of digital technologies (Galla 2016). These dynamics mirror the challenges faced in initiatives such as Wiki Papa and VarScout app, where custodians' offline stewardship practices are not always easily aligned with online stewardship and digital infrastructures.

The sociotechnical issues that rural communities and Indigenous Peoples face when accessing digital technologies are not only the result of a digital divide but also reveal concerns related to the collection, ownership, and dissemination of Indigenous data. Indigenous data sovereignty has emerged as a means for Indigenous peoples to assert their rights over their data (IWGIA n.d.). Data sovereignty emphasises that Indigenous communities should have the authority to make decisions about how their data are collected, accessed, and used, aligning with their self-determination and governance structures (Carroll et al. 2020; Garba et al. 2023; Hudson et al. 2023; Oguamanam 2020). Data management practices should respect Indigenous sovereignty, prioritising Indigenous values and knowledge systems.

Indigenous data sovereignty also interacts with broader data governance principles used by experts to assess equity, user feedback, collective benefit, and situated understandings of data practices. Taken together, the FAIR and CARE principles were designed to support ethical and transparent data governance practices and collaborations. As mentioned above, FAIR stands for findable, accessible, interoperable, and reusable data (Wilkinson et al. 2016). CARE acknowledges the status and relevance of Indigenous peoples in decision-making, especially regarding the use of data about themselves, their lands, and their waters (Carroll et al. 2020). Whilst the FAIR principles were designed to ensure the usability and accessibility of data, they do not explicitly address the

needs, interests, and rights of Indigenous peoples, who have historically been marginalised in global data practices. The CARE principles emerged in response to growing concerns that global data initiatives, including the open data movement, often overlook the unique rights and cultural values of Indigenous communities (Carroll et al. 2020).

Ethical concerns about data, as well as data governance principles, have also emerged as a response to datafication. Datafication is a process defined as the 'transformation of social lives and identities into quantified data' (van Dijck 2014). It recognises non-expert knowledge only insofar as it can be commodified or embedded in economic relations (Mejías and Couldry 2019; Ricaurte 2019). In addition to FAIR and CARE, data audits are another method that can foster citizen empowerment in relation to their data. Data audits examine citizens' situated affective responses to datafication (Reilly and Morales 2023) and prioritise citizens' perspectives and responses to information systems by focusing on how they experience datafication. This includes citizens' participation in the production of culture, heritage, tradition, and literacy (Reilly and Morales 2023).

This section has sought to explain how the digital divide, as a by-product of the data economy, has not only generated gaps in digital skills and infrastructure but also concerns about the limited spaces for public deliberation on ethics and data sovereignty. Whilst there is significant awareness of the digital divide among rural communities and Indigenous Peoples, there is less awareness and knowledge about why data are being collected, by whom, and how they will be used. This makes it possible to critically examine Wiki Papa and VarScout, not only as technical tools but also as sites where questions of data sovereignty, ethics, and equity come to the fore.

3. Methodology and Methods

This study combined semistructured interviews, participatory observation in workshops, and documentary analysis to examine how data platforms interact with agrobiodiversity data, and how data sovereignty intersects with questions of data stewardship.

This chapter adopts a multi-sited approach (Marcus 1995; Hannerz 2003) that follows the interplay of online and offline interactions around

Wiki Papa and VarScout. Online platforms and face-to-face encounters are not separate domains, but rather interwoven spaces through which participants construct identities, communities, and practices (Watson 1997; Miller and Slater 2000). In this sense, Andean communities uploading potato data offline due to limited internet access are part of the same community as extension workers or students who engage with the platforms online.

Fieldwork involved ten semi-structured interviews with key actors in the Wiki Papa data chain: three developers and data curators, two representatives of Miski Papa (an online delivery platform for Andean potatoes in Lima), two members of the technology consultant team who organized citizen science workshops, and three researchers from Grupo Yanapai, a local NGO that works with Andean farmers. These interviews provided insights into how different actors conceptualize potato agrobiodiversity, the challenges of integrating local knowledge into digital infrastructures, and the expectations attached to Wiki Papa.

In addition, J.S.Z.V. collaborated with the consultant team to facilitate three citizen science workshops in the regions of Junín and Huánuco. These workshops brought together three distinct groups: farmers from AGUAPAN, the Peruvian Association of Native Potato Guardians (fourteen participants across six regions, slightly familiar with smartphones); extension workers from NGOs and government agencies (eleven participants, all smartphone users with moderate app use); and university students (ten participants, aged 20–30, with high engagement with smartphones). This comparative design offered a lens on digital skills, access, and expectations across user groups, while also highlighting gaps in participation and the ways data stewardship practices unfolded.

To complement these data, J.S.Z.V. analysed the most recent regional potato agrobiodiversity catalogues (La Libertad 2023; Huancavelica 2021; Junín 2017) incorporated into Wiki Papa. Using Python, we transformed catalogue information into Excel tables while preserving their descriptors (names, synonyms, morphological traits, nutritional value, agronomic features, culinary uses). This approach enabled us to examine how Western scientific categories mediate the representation of agrobiodiversity in digital infrastructures, and how such classifications intersect with Indigenous knowledge systems and data stewardship practices.

The analysis followed the principles of grounded theory (Charmaz 2014), emphasizing iterative coding, constant comparison, and memo-writing. The open-source software Taguette was used to code interviews, workshops, and documentary materials. Analytical categories included: data science, data justice, citizen science, digital literacy, e-commerce, Western classification, value chains, technology acceptance, local potato names, and internet access.

The second author, J.A.D., contributed to drafting the initial reports derived from this research, offering guidance on how to better present its central arguments and organise paragraphs and sections coherently, while maintaining a clear focus on the interview analysis and qualitative coding.

4. Background: Cataloguing Andean Potatoes

CIP has been working alongside custodian potato farmers to increase potato agrobiodiversity conservation efforts in situ and ex situ. Founded in 1971 as a research-for-development centre (CIP website n.d.), CIP is an important organization for conducting reintroduction of potato varieties that are in danger of disappearing or that are no longer available (Westengen et al. 2018). CIP is recognized as the largest in vitro gene bank in the world, housing one of the most extensive herbarium collections and prominent plant cryopreservation programs (CIP Genebank website n.d.). Concerns about the long-term security of CIP's plant material collection, alongside technologies like cryopreservation, reflect ongoing efforts to adapt and improve gene bank practices (Vollmer et al. 2022).

CIP is part of the Consultative Group on International Agricultural Research (CGIAR) network, a global partnership of research centres like the International Rice Research Institute (IRRI) and the International Maize and Wheat Improvement Center (CYMMYT). CGIAR's work focuses on multidisciplinary research on specific commodity crops and ecoregions, aiming to reduce hunger (Byerlee and Lynam 2020). CGIAR's network centres sought to create efficiencies through economies of scale and scope (Byerlee and Lynam 2020), generating efficiencies and spillovers through applied research networks that freely shared materials and knowledge. CIP's genebank operates within a

global collaborative network of genebanks (Engels et al. 2024). In Peru, CIP collaborates with Peruvian research agencies like the National Institute of Agrarian Innovation (INIA, Spanish) in Peru (CIP 2018). Beyond research and capacity, CGIAR's centres aimed to reduce political and bureaucratic interference in science and secure long-term funding through foreign aid and philanthropic organizations (Byerlee and Lynam 2020). With the arrival of the Sustainable Development Goals (SDGs) in 2012 (UN General Assembly 2012), CIP adapted its organizational structure to address goals such as reducing poverty and hunger, particularly in Africa (CIP 2019). To fulfill those goals, CIP mediates between the policy-making, regulatory and social dimensions of international agriculture. This mediation is generally defined as boundary work defined as the 'interface between science and policy' (Clark et al. 2016) and the 'activities of those seeking to mediate between knowledge and action' (Clark et al. 2016).

CIP cataloguing activities can be thought of as a continuation of CGIAR's efforts to gather plant genetic resources since the 1950s (Montenegro 2016). Potato collections at private and public facilities began before CIP's foundation in 1971, with expeditions led by Peruvian scientists such as Carlos Ochoa (Ringle 1992). More recently, in 2021, CIP collaborated with AGUAPAN, an association of custodian potato farmers, to identify new cultivars not previously included in its collection (CIP 2021). The first CIP potato catalog was developed in 2006 in the region of Huancavelica, featuring 144 varieties and 21 households. Fifteen years later, another catalog from the same region was elaborated, featuring 185 varieties and 16 households. Other catalogs include Apurímac in 2014, La Libertad in 2015 and 2023, and Junin in 2017 (Wiki Papa 2024).

Wiki Papa uses data from VarScout, a biodiversity app developed by Resonanz Group, a Swiss tech company (CIP 2024; VarScout 2024). VarScout is the main tool that stewards possess to upload data to Wiki Papa. VarScout was designed to collect data for purposes other than potato conservation, such as real-time decision-making on investments in crop breeding and seed systems (MacMillan 2024). VarScout's partners are working with the Ministry of Agriculture in Kenya to train extension officers to use VarScout to collect varietal data from bean, maize, and potato farmers to determine the abundance, turnover, and performance of crop varieties and mitigate climate change (CGIAR

2024). In Peru, VarScout operates as a citizen science project that fosters potato conservation. In this context, citizen science refers to the active participation of non-professional actors in generating and sharing knowledge for conservation and broader scientific goals (Cooper 2016; Hine 2020; Strasser et al. 2018).

This section has reviewed the role and activities of CIP as a research-for-development organisation, not only committed to protecting potato germplasm collection, but also to helping reduce poverty and hunger. To achieve this, CIP mediates with public and private partners, as well as with donors and international aid to secure funding for its research and development programs in Peru and other regions. Additionally, as a result of these activities, CIP developed catalogues to close data gaps in its collection, as well as to engage farmers in potato conservation. Thus, Wiki Papa and VarScout, should be seen as a continuation of CIP cataloguing efforts to gather Andean potato data. However, these digital platforms raise questions about whose knowledge is represented, how it is categorised, and how rural and Indigenous farmers benefit from online data practices.

5. Analysis: Data Curation and Data Collection Practices

This section examines two activities central to CIP's online cataloguing efforts to address data gaps in agrobiodiversity research: data curation and data collection. Both practices have long been embedded in CIP's research and development programmes, carried out in collaboration with rural communities.

The introduction of digital platforms such as Wiki Papa and VarScout has altered the ways in which curation and collection are undertaken. Through Wiki Papa, data curators now operate in a digital environment, while students, farmers, and extension workers upload their own data to the platform. Although local knowledge is valued as a key source of information, Western-trained experts continue to exercise authority in deciding which data are incorporated. Similar to Wiki Papa, VarScout was also conceived as a citizen science platform to enable Andean communities to contribute to reducing knowledge gaps. Rather than integrating their feedback into its design, however, workshop sessions

only focused on training participants to operate the app. The following section explores how these tensions between expertise, participation, and authority in data practices intersect, and why they remain problematic for agrobiodiversity conservation and Indigenous data sovereignty.

5.1 Arbiters of Agrobiodiversity

This section explores the views that Wiki Papa developers have about agrobiodiversity data curation and the role that curators play in formalising and validating the data collected by Wiki Papa users. Curators, who are Western-trained potato agrobiodiversity experts, act as arbiters of agrobiodiversity when they formalise and validate VarScout users' field observations (images, potato names, as well as morphological, agronomical descriptors). During the interviews and the workshops, scientific expertise played an important role in deciding which data is included in Wiki Papa. Whilst examining the Wiki Papa online catalogue, we noticed that Western descriptors such as agronomic and morphologic potato traits were very detailed. Curators' decisions have a direct impact on how users' data is treated and ultimately, what counts (and does not count) as data. Given that Wiki Papa is a citizen science project, it is worth examining how it complies with FAIR and CARE principles, since decisions about potato data should respect the rights and self-determination of Andean communities.

Even though FAIR and CARE were not explicitly mentioned during fieldwork, they are used in this chapter as a way to analyse the limits of Indigenous data sovereignty. FAIR has positively influenced the accessibility and findability of Andean potato agrobiodiversity data, especially for experienced VarScout users. Wiki Papa developers knew that they needed to include data from past potato agrobiodiversity catalogues, since their goal was to make the information collected in those catalogues available online. The effort to organise data from previous catalogues aligns with FAIR principles and shows a commitment to open and make accessible potato agrobiodiversity data. By 2022, Wiki Papa developers and curators started to develop a database of potato varieties from regional potato catalogues. The diversity of potato cultivars and the identification of atypical names were examined using statistics and processing algorithms.

Wiki Papa's developers placed significant focus on data curation,

often called the 'cleaning' process, indicating a commitment to high-quality standards. This process seeks to guarantee that the data provided is accurate and reliable—a requirement for FAIR compliance. This process ran concurrently with the development of Wiki Papa over three months. The resulting database expanded with the addition of photos that accompanied the curated metadata. Since then, Wiki Papa has been integrating more information, such as tuber skin colour, tuber size, culinary uses, and yield. The way the information is presented in Wiki Papa is similar to how data and Western standards are included in the regional agrobiodiversity catalogues that are published in physical form. As mentioned before, these publications tend to provide detailed information of Western descriptors of potato agrobiodiversity that may not resonate with Andean communities' stewardship practices.

Nevertheless, Wiki Papa developers acknowledged that 'you cannot force, nor can you change the way farmers think' (Interview with Wiki Papa developer 2, 21 March 2023). As such, efforts were made to incorporate synonyms for varieties used in regional potato catalogues in hopes of making the platform more accessible to Andean farmers and allowing them to identify local potato varieties using colloquial terms. The incorporation of synonyms shows sensitivity towards names of Andean potatoes in Quechua. This acknowledges the relevance of Indigenous classification for potato conservation, respecting CARE. However, a developer admitted that there is a risk that users 'may not find it (the potato) with the name they know,' as potato naming practices vary across regions, with some varieties having up to eight synonyms, according to the Wiki Papa catalogue (Interview with Wiki Papa developer 2, 21 March 2023).

In an effort to standardise diversity, curators play a crucial role in 'formalising' data and building trust between VarScout users and Wiki Papa, contributing to the accessibility and reliability of the information, aligning with FAIR. From the perspective of the Wiki Papa developers, the role that curators play in formalising data ensures reliability and integrity of the data provided, which makes sense from a citizen science approach to data collection. For them, there is a need to include farmers and local communities' observations to close the data gaps and maximise the varieties registered, since even expert curators might not find all the native potatoes in 'one or even one hundred trips' (Interview with Wiki

Papa developer 2, 21 March 2023). Wiki Papa developers consider that citizen science platforms should help mitigate agrobiodiversity loss and need to be used as a supportive tool to in situ conservation practices, aligning with CARE.

Wiki Papa developers mentioned that curation does not imply the loss or alteration of VarScout users' observations. Rather, they argue that users will benefit from expert knowledge who would assist them in identifying novel potato varieties. Western-trained data curators, according to the developers, help 'formalise' users' observations. When asked about what it is like to formalise observations, they mentioned that it would be similar to giving them a 'birth certificate.' Deciding which observations are 'correct' would imbue curators with power over Indigenous data, since VarScout users are Indigenous people or engage with them to collect potato data. This implies that decisions about Indigenous data, even in cases where new varieties are identified, remain in the hands of curators. This challenges CARE, since 'formalising' users' observations are not formally included until data is verified by the Western-trained experts. Data science, in practice, favours Western arbiters' decisions on what to include, when and how data should be included.

The discussion about the formalisation of users' data, the prevalence of Western expertise over Indigenous data, and the reduction of Indigenous knowledge to verifiable data, aligns with the notion of top-down citizen science projects. This concept describes projects where the authority to determine the criteria for what counts as knowledge resides with developers (Hine 2020). At the same time, the good intentions behind Wiki Papa developers' belief that digital platforms would provide supportive tools for Andean communities seems logical from this perspective. However, placing emphasis on Western expertise to decide which data is included limits bottom-up data stewardship practices rooted in data sovereignty.

Looking at the future, Wiki Papa developers argue that the involvement of curators will allow users to engage in discussions about data validation. They predict that VarScout users will follow these discussions online, interacting with curators whilst retaining the ownership of their data. However, developers did not provide specific details on how that could be achieved in practice. Whilst it is not clear how VarScout users will interact with potato curators, Wiki Papa developers

have optimistic attitudes about the future of curation. Tech-optimism, understood as the view that technology is 'the key to unlocking a better world' (Danaher 2022), can raise the user's expectations about the future of emerging technologies such as Wiki Papa and VarScout. Raising expectations in a context where it is not clear how users will retain ownership and have control over their data challenges Indigenous data sovereignty. Having active control of how data is handled and whether Indigenous data stewards have a say in that process is imperative for empowering local contributors and community members.

In the context of FAIR and CARE, there is tension between user autonomy and expert data curation. Whilst FAIR advocates for making data accessible and reusable through community contributions, CARE principles emphasise Collective Benefit and Authority to Control, which should ensure that users maintain control over their data. However, in practice, Wiki Papa curators act as gatekeepers, filtering incomplete observations and determining which data is included, which can undermine Indigenous data sovereignty. This dynamic reflects a challenge in balancing data reliability with empowerment, signalling a disconnect between the intended goals of FAIR and CARE and the realities of platform design and implementation.

5.2 Workshops as Training Sessions

Building on CIP's long-standing use of participatory methods, Wiki Papa workshops introduced VarScout as a citizen science tool for collecting potato data. VarScout users' contributions were expected to play a central role in building the Wiki Papa catalogue and improving the VarScout app. In practice, however, workshops emphasised training users to operate VarScout rather than eliciting feedback to contextualise and redesign its interface. This section examines VarScout users' experiences during the workshops, the barriers they encountered, and the implications for FAIR, CARE, and Indigenous data sovereignty.

During the workshops, VarScout was presented as a citizen science app for data collection. Not all VarScout users were aware of the Wiki Papa platform, nor of its interaction with Wiki Papa as a unified citizen science project. Wiki Papa developers believe that VarScout can become more user-friendly and adapted to different users, not just

Andean farmers. Wiki Papa developers and their partners at CIP can request VarScout developers to modify the app, integrating feedback as new versions of it are developed. This represents an opportunity for conducting early ethical assessment of open knowledge infrastructures, via frameworks such as responsible innovation (Stilgoe et al. 2013).

VarScout design and interface issues challenge FAIR and CARE compliance and show barriers to achieving Indigenous data sovereignty, since access to the app depends on digital literacy, familiarity with smartphone apps, and internet availability in rural areas. This generates a divide in terms of user profiles and their ability to engage with both platforms. Whilst these knowledge infrastructures remain inscrutable for first-time users such as farmers, they are more accessible to students and extension workers who collect data from Andean farmers. These users tend to have more stable internet access than farmers and are also familiar with other data platforms such as KoboCollect, a free open-source Android app that lets users fill out and upload survey forms, even without internet access, as part of the KoboToolbox platform (Kobo Collect).

User experience plays a vital role in the successful implementation of data collection platforms like VarScout, especially in ensuring user engagement and data quality. Realising that users might experience difficulties using this type of platform, developers pointed out that VarScout and Wiki Papa need to be simpler and more intuitive. According to them, users must have an 'intuitive experience' and should feel motivated to upload data themselves rather than perceive it as an imposition. However, users' experiences often contradicted this statement. Most farmers identified issues with the interface, such as the app's intense brightness, difficulty reading small fonts, and challenges with sun reflection and colour. During the workshops, farmers expressed that whilst they enjoyed taking photos of their potatoes, they had trouble locating images within the app. Additionally, they struggled to re-log into VarScout after taking pictures or using other apps.

Understanding the experiences of farmers is crucial for assessing the effectiveness of the FAIR and CARE principles in the context of agricultural technology regarding their interactions with tools like VarScout. During the workshops, many farmers faced some challenges using the app. Facilitators linked those challenges to poor or lack of digital literacy skills as well as absence of proper infrastructure such

as reliable internet. Furthermore, farmers were only introduced to VarScout, which was considered disrespectful by some workshop facilitators due to potential concerns about treating farmers as data collectors. As noted in the methodology section, farmers recruited for the workshops were already slightly familiar with smartphones, which partly explains their initial disposition to participate in the workshops but also highlights the challenges that less digitally skilled farmers could face whilst accessing VarScout.

Regarding VarScout's operability, farmers stated that 'it should not be mandatory to fill out everything, but it could be important to have the knowledge [to use VarScout].' This is in reference to the forms required by the app to set up their user profiles and background information, as well as Western categories such as morphological and agronomic descriptors. Often, farmers felt overwhelmed by the level of detail of the information required by VarScout. For them, the most exciting feature of VarScout is that it allows them to take pictures of their potatoes and then locate them on the app's map. During the workshops, potato farmers were asked about the amount of observations each of them could provide per week to estimate their interest in the app. Nevertheless, after several months of the workshop, few of them uploaded images via VarScout.

Most of VarScout users' experiences focus on direct interaction with the app, and how it appeals to them in terms of sensoriality. Sensoriality is defined as the 'act of signifying the world from our senses,' including biological perception and sociocultural standing (Valquiria, Regiane, and Gerson 2019). Thus, they should not be relegated to mere opinions on how new technology operates, but instead they should be examined as situated understandings of agrobiodiversity knowledge infrastructures. At the same time, it is relevant to acknowledge the complex power dynamics between experts, non-experts and participants in citizen science, and how that can lead to interventions that validate the data collection practices that do not emphasise CARE.

Data audits help us to examine users' experiences, senses, and perspectives by recognising their agency in the production of culture (Reilly and Morales 2023). Although workshops were framed as opportunities for deliberation, in practice they became training sessions. This dynamic limited critical feedback, left some farmers feeling evaluated, and reinforced the top-down emphasis on data collection

over ethical reflection. This was an issue since it was challenging to elicit honest user feedback. Some users felt evaluated, whilst others felt compelled to agree with workshop facilitators. Those who voiced their concerns mainly focused on VarScout's interface, especially on problems with its design and accessibility for users scarcely familiar with smartphones.

These challenges indicate potential barriers that may disproportionately affect users who lack familiarity with smartphone use, emphasising the need for an inclusive platform design more tailored to their practical needs. To examine FAIR and CARE compliance, users require more resources to engage in data governance, such as having a comprehensive knowledge of how the platform collects, shares and stores data. Nevertheless, during the VarScout workshops, deliberation and critique were not actively encouraged. Without meaningful opportunities for critique, workshops risked validating a narrow conception of participation: farmers as data collectors rather than stewards of agrobiodiversity knowledge infrastructures.

6. Discussion

Building on the findings from the analysis of the workshops and Wiki Papa implementation, this discussion addresses three interrelated themes: a) the digital divide, b) data sovereignty, and c) datafication. The aim is to examine how tensions between expertise, curation, participation, and data collection shape knowledge infrastructures and why this is problematic for non-Western users, particularly Andean farmers.

The digital divide in rural areas and amongst Indigenous peoples is often framed as a problem of limited infrastructure or lack of digital literacy. Yet, as Rotondi et al. (2020) and Ávila (2023) argue, inequalities are not only about access but also about cultural and linguistic barriers. Our analysis of the workshops shows that even when infrastructure and training were provided, inequalities in participation persisted. Farmers often perceived workshops as training sessions rather than deliberative spaces, which limited their agency and positioned participation as compliance rather than co-creation. This suggests that reducing the digital divide through investments in connectivity and digital skills is insufficient. Participation depends on whether technologies are

introduced in ways that are meaningful. As Ragnedda (2017) argues, the digital divide is as much about social justice as about access.

Data sovereignty further illustrates these tensions. Wiki Papa emphasises FAIR compliance by ensuring that data are findable and reusable, but the authority to decide which data are included remains with Western-trained experts. Indigenous categories and knowledge systems are not fully integrated, thereby limiting CARE compliance and Indigenous data sovereignty. As Carroll et al. (2020) and Hudson et al. (2023) highlight, FAIR principles alone cannot safeguard Indigenous interests. Wiki Papa exemplifies how sovereignty is limited when descriptors and measurement units privilege Western science over local categories. Asking 'who benefits from Wiki Papa, and what does that look like in practice?' becomes central, since Indigenous Peoples are asked to share their data without being guaranteed authority over how that data is represented or used. Sovereignty, as Oguamanam (2020) emphasises, must extend beyond participation to include decision-making power and recognition of Indigenous values.

Wiki Papa and VarScout reveal how participation can be viewed as data provision, aligning with critiques of datafication (van Dijck 2014; Mejías and Couldry 2019). During workshops, users with limited digital skills were not always asked why or under what conditions they would want to use these platforms. Instead, participation was structured around how to supply standardised data, often framed in Western categories. Citizen audits, as proposed by Reilly and Morales (2023), offer a counterbalance by examining affective and situated responses to data infrastructures. Yet in practice, workshops emphasised training over deliberation, leaving little room for critique of interface design, accessibility, or ethical concerns.

Without spaces for early ethical assessment, knowledge infrastructures such as Wiki Papa and VarScout risk limiting Andean communities' engagement in online stewardship. To move beyond this, citizen science in agrobiodiversity must integrate deliberation, recognition, and incentives that affirm Indigenous stewardship and sovereignty, ensuring that participation is not only about supplying data but also about shaping how knowledge is governed and used.

7. Conclusions

FAIR and CARE principles were partially implemented in Wiki Papa, but significant challenges remain in understanding what users' contributions mean for them and how their involvement actually supports closing data gaps. The case of Wiki Papa and VarScout underscores the need to distinguish between online and offline stewardship, and to recognise how data stewardship practices shift when mediated by digital infrastructures.

The findings point to three persistent challenges. The digital divide continues to shape who can meaningfully participate, extending beyond connectivity to include socio-cultural and linguistic barriers. Second, data sovereignty remains limited when decision-making power rests with Western-trained curators rather than with Andean communities themselves. Third, datafication risks reducing participation to data provision, limiting deliberation and the situated ways in which Andean stewards engage with potato agrobiodiversity.

There is potential for Wiki Papa to positively impact farmers' livelihoods. Greater compliance with CARE could be achieved if community members were included as arbiters of their own knowledge. Likewise, workshops should extend beyond technical training to deliberate on the broader implications of digital participation, including whether user engagement yields tangible and meaningful benefits for participants.

Moving towards equitable agrobiodiversity data governance requires embedding Indigenous data sovereignty in practice, not just principle, and ensuring that stewardship is not reduced to data provision but expanded to include authority, deliberation, and recognition of Indigenous knowledge systems.

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12. Opening Network Infrastructures: The Sociomaterial Politics of Openness in Grassroots Community Networks

Stefano Crabu

1. Introduction

> Sometimes someone says: 'Excuse me, but is it not enough that the internet is already working? Why is it not enough to request that the municipality put internet in areas still not covered?' This question is a challenge for all of us, and we want to contribute to building a parallel infrastructure, which has grown over time and represents a space of freedom. (Italian community wireless network activist interviewed by the author)

This opening quote reflects the perspective of an Italian activist involved in Ninux.org—a pioneering grassroots initiative in Italy committed to the collective construction of digital communication infrastructures as a counter-hegemonic alternative to the corporate, centralised architecture of the mainstream internet (see Crabu et al. 2015). Although articulated in technical terms, his intervention foregrounds a central concern in current social science debates on infrastructuring processes: digital infrastructures are not merely functional assemblages enabling data transmission, but deeply political artefacts entangled in the modulation of power, rights, and forms of citizenship. They constitute contested terrains where technical arrangements and politics are inextricably intertwined (Edwards 2010).

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This perspective frames grassroots digital infrastructuring initiatives like Ninux.org not merely as technical projects, but as socio-technical interventions—deliberate efforts to reconfigure power relations within the dominant landscape of digital governance. By constructing alternative networks, grassroots initiatives expose how mainstream digital infrastructures are never merely technical supports for connectivity, but rather sites where governance, corporate control, and resistance intersect. Under this lens, digital communication infrastructures are increasingly conceptualised as dynamic socio-technical systems that shape access to knowledge, mediate forms of civic engagement, and generate new modalities of inclusion and exclusion (Larkin 2013; Plantin et al. 2016). As such, infrastructures are sites of contestation where values, resources, and imagined futures are materially negotiated (Parks & Starosielski 2015). The design, maintenance, and visibility of digital infrastructures—who builds them, who governs them, and who can access them—are central to broader conflicts surrounding surveillance, sovereignty, and social justice in the digital age.

Infrastructure, in this view, is a form of slow, enduring governance—shaping the very conditions under which political agency can emerge. Michael Mann's (1986) historical account of infrastructural power underscores how communication systems have historically served as levers of administrative control and statecraft, facilitating both territorial integration and surveillance. In dialogue with this, Barry (2020) conceptualises infrastructures as dynamic and contested configurations of technical devices, standards, and institutional logics that transgress and rearticulate political and spatial boundaries. Digital infrastructures, in this sense, are not just media of connection, but instruments of (counter)governance—material embodiments of political ideologies, imaginaries of citizenship, and epistemic regimes.

One of the most pertinent contemporary sites for examining the mutual shaping of politics and infrastructures is that of Community Networks (CNs), including initiatives such as Ninux.org. Over the last two decades, CNs have gained increasing visibility in public discourse and among policy makers as grassroots network infrastructures offering alternative models to commercial or state-led internet provision (Van Oost et al. 2009; Verhaegh and Van Oost 2012; Shaffer 2020). Typically designed, built, and maintained by local collectives, these networks propose different

configurations of ownership, governance, and technical architecture that seek to decentralise control and enhance autonomy. They are thus not only technical artefacts, but also socio-political projects aimed at democratising internet access and reconfiguring the politics of connectivity. Technically, many CNs adopt a mesh or distributed architecture. In mesh networks, each node (or device) can connect directly to multiple other nodes, without relying on a central router or single point of control. This enables decentralised and resilient connectivity: if one node fails, data can be rerouted through others. Mesh networks can dynamically reconfigure themselves in response to changes in the environment, providing robust performance in underserved or challenging contexts. This form of technical decentralisation is not incidental—it directly aligns with the political ethos of CNs, reinforcing values of autonomy, redundancy, and collective management (Maccari et al. 2016).

This shift becomes particularly salient in a context marked by the increasing centralisation, commodification, and infrastructural opacity of the global internet (Van Dijck et al. 2018; Zuboff 2019). Under the governance of a small oligopoly of platform monopolies, contemporary digital infrastructures are organised around extractive data economies, algorithmic opacity, and asymmetrical control over standards and access (Sadowski 2019). In this regard, the infrastructural turn in platform studies highlights how power is exercised not only through content moderation or interface design, but through the technical and logistical arrangements that structure participation, constrain autonomy, and mediate visibility across networks (Parks 2015).

Against this backdrop, CNs position themselves not merely as oppositional trajectories, but as prefigurative infrastructures—initiatives that enact alternative socio-technical configurations grounded in horizontal governance, free/libre/open-source software, and cooperative models of maintenance and care. These initiatives challenge the dominant digital infrastructural regime by foregrounding user agency, collective ownership, and epistemic transparency. In doing so, CNs contribute to reimagining digital connectivity as a shared civic resource rather than a privatised service, articulating modes of digital citizenship that resist enclosure while enabling experimentation with new forms of democratic networked life.

This chapter examines how the politics of openness is enacted

through grassroots infrastructuring practices, focusing on the case of CNs. Drawing on science and technology studies (STS)—particularly infrastructure studies (Bowker and Star 1999; Star and Ruhleder 1996; Karasti et al. 2004; Karasti et al. 2006) and critical media scholarship (Gillespie et al. 2014; Barry 2020)—I approach openness not as a fixed attribute or normative ideal, but as a situated, emergent sociomaterial achievement. Rather than framing openness as a stable value associated with accessibility, transparency, or participation, I examine how it is actively constituted within the infrastructuring work of designing, maintaining, and governing communication networks. Building on Hartley et al. (2018), who conceptualise the 'politics of openness' as the interplay between normative commitments to transparency and the contested practices through which openness is enacted, this chapter further develops the term by situating it empirically in the grassroots infrastructuring of Ninux.org. Here, the politics of openness is not only an analytical lens but also a lived practice, made tangible through governance arrangements, technical decisions, and sociomaterial negotiations.

Indeed, what this formulation implies for practical engagements with infrastructures remains far from straightforward: What does it mean to prioritise openness while simultaneously shaping stable, functional systems? How do actors navigate the tensions between the aspiration to openness and the often rigid material and organisational demands of infrastructural design? These tensions highlight that openness is not an a priori condition to be embedded into infrastructures, but a contingent and contested outcome of socio-technical negotiations. The term 'politics' in this context serves to foreground the performative and situated nature of openness—particularly, its emergence through the iterative entanglement of governance practices, technical decisions, political imaginaries, and infrastructural constraints.

Following Winner's (1980) insight that 'artifacts have politics,' I argue that technologies such as routing protocols, antennas, and open-source platforms do not merely support openness but shape its meaning and boundaries. Infrastructures, from this angle, are not passive enablers of political values but active sites where those values are materially negotiated and made durable or, at times, rendered fragile. Openness is thus enacted through technical constraints, not in spite of them but

via hybrid collectives of human actors and heterogeneous materials engaged in practices of configuration, maintenance, and governance. Rather than seeking fixed definitions of openness, this chapter proposes to investigate its multiple instantiations as a doable problem—a practical, ongoing effort that requires continuous negotiation and adaptation. It is within this processual framing that the politics of openness can be meaningfully explored. What openness becomes in practice depends not only on normative aspirations but also on the infrastructural settings through which it is pursued. Hence, the guiding question of this inquiry is not whether CNs are 'open' or not, but how openness is done, by whom, with what tools, and with what consequences.

This approach enables a relational understanding of openness as both a political and socio-technical phenomenon—always situated and in-the-making. Empirically, this chapter draws on a multi-sited qualitative study of Ninux.org conducted between 2014 and 2015. The fieldwork included eleven semi-structured interviews with long-term members of four local nodes (Rome, Pisa, Bologna, Florence), participant observation at national meetings, and analysis of collaborative infrastructures such as wikis and mailing lists. Informants included hackers, engineers, and activists engaged in the technical and political life of the network. Many participants described Ninux.org as a 'gymnasium of experimentation,' where technical skills and political subjectivities are co-constructed through ongoing infrastructuring work. In this context, Ninux.org is used as an instrumental case study, not because of its uniqueness per se, but because it helps illuminate broader processes at stake in the enactment of openness within grassroots infrastructures. The case illuminates how openness is materially and discursively shaped in practice, and how technologies act as mediators that configure, enable, or constrain the performative dimensions of openness. Rather than asking what openness means in normative terms, this chapter investigates how it is enacted through specific constellations of practice—mobilising technical expertise, material infrastructures, political values, and governance arrangements. By centring the case of Ninux.org, the chapter also contributes a geographically situated analysis from Southern Europe, adding to the global conversation on grassroots infrastructures, openness, and digital sovereignty. While much of the literature has focused on cases from the

Global North or on high-profile initiatives in urban innovation hubs, this chapter foregrounds a different infrastructural geography—one shaped by uneven state investment, volunteer labour, and alternative imaginaries of connectivity. This situatedness reveals how openness is not only a technical or political ambition, but also a response to concrete local conditions, institutional voids, and infrastructural discontinuities.

The structure of the chapter reflects this analytical orientation. It begins by tracing a genealogy of community networks as a socio-technical movement, following their evolution from early experiments in countercultural computing to more recent developments in mesh networking. The subsequent analysis unfolds across closely interconnected dimensions through which the politics of openness is enacted in practice. First, the chapter explores the governance models and participatory arrangements through which CNs operate. It then turns to the material and maintenance practices that sustain infrastructure over time, highlighting how care, repair, and technical labour are essential to the enactment of openness. Taken together, these dimensions show that CNs such as Ninux.org are not merely alternatives to commercial internet provision—they are experimental and contested arenas where openness is continuously performed. Their political significance lies not only in the values they promote, but in the situated, materially grounded, and collectively sustained practices through which they make those values operative.

2. The Long Journey Toward Opening Network Infrastructures: The Genealogy of Community Networks

The increasing centralisation of digital infrastructures, coupled with neoliberal regulatory frameworks that foster commodification and surveillance, has catalysed renewed interest in distributed, community-rooted alternatives. In this context, CNs are not only infrastructural responses but also political interventions that contest dominant regimes of connectivity and control. This section traces the historical and socio-technical genealogy of CNs, situating them within the broader landscape of infrastructural studies, and foregrounding their embeddedness in the politics of openness, autonomy, and self-governance.

CNs are grassroots initiatives aimed at collectively building and managing communication infrastructures, often structured around the principles of the digital commons (Bollier 2008; Velicu and García-López 2018). While they provide internet connectivity, their deeper function is to reimagine infrastructure as a domain of collective action and civic empowerment. CNs exemplify a kind of 'material participation' (see Le Dantec and DiSalvo 2013; Marres 2012), where technical design and deployment become vehicles for democratic engagement. These networks are not simply alternatives to corporate ISPs; they instantiate counter-hegemonic models of infrastructural governance based on transparency, horizontality, and mutual aid. Organised through hybrid collectives of technologists, activists, hobbyists, and occasionally municipal authorities, CNs materialise at the intersection of technical experimentation and political imagination (Shaffer 2020).

These collectives, however, do more than operate infrastructure; they actively reconfigure the epistemic and material conditions of digital networked environments by engaging in struggles over ownership, visibility, and the governance of technical systems that shape everyday life.

The roots of CNs extend back to early pre-commercial internet cultures, emerging from countercultural movements that framed computing as a tool for collective empowerment. Early initiatives, such as Berkeley's 1973 Memory Project, were deeply embedded in the ethos of the homebrew computing and DIY movements, envisioning decentralised technology as a means of fostering community autonomy and resilience (Levy 1984). These projects aligned with broader critiques of centralised media systems and drew inspiration from radical media traditions—including pirate radio and the underground press—that prioritised self-managed communication (Downing 2001). Armin Medosch's (2008) work on Freie Netze underscores how early European wireless experiments fused libertarian political traditions, creating socio-technical infrastructures that prefigured later CNs.

The 1980s–1990s saw CNs proliferate across North America and Europe, coinciding with telecommunications liberalisation and the rise of personal computing. Free-Nets and Bulletin Board Systems epitomised this wave, leveraging nascent connectivity tools to cultivate localised publics (Turner 2006). Projects like the Seattle Community Network and Cleveland Free-Net not only filled infrastructural voids but also

exemplified what Sandvig (2004) describes as collectivities, constituted through shared engagement with infrastructure. These efforts reflected a socio-technical imaginary of the internet as a participatory, civic resource rather than a privatised commodity. Yet, such formations were neither widespread nor uniformly emancipatory. As Köhn (2025) demonstrates in the Cuban context, CNs often emerged in response to conditions of scarcity or state repression, highlighting how infrastructural practices are contingently shaped by local political economies and social struggles. This tension underscores a central paradox in CNs: while they aspire to democratise access, their trajectories remain entangled with broader structures of power (Star 1999).

The early 2000s marked a shift in CNs' scope and scale, bolstered by the availability of affordable Wi-Fi technology and open-source firmware. Initiatives such as Freifunk in Germany (Vaseva 2016), Guifi.net in Spain (Vega et al. 2012), and Zenzeleni Networks in South Africa (Hussen et al. 2016) revealed diverse governance configurations, from radically horizontal collectives to more structured community associations.

These projects challenge any idealised or singular model of community networks. For instance, while Freifunk champions a decentralised vision grounded in hacker ethics and anti-surveillance principles, Zenzeleni reflects a form of infrastructural pragmatism, where connectivity solutions are shaped by the immediate needs of under-served rural communities. Moreover, CNs in the Global South often reveal how infrastructuring efforts are motivated less by aspirations of political autonomy and more by the urgency of securing basic access. Taken together, these cases illustrate the diverse logics and practical considerations that drive CN development, highlighting the multiplicity of motivations, values, and operational models at play. Thus, CNs increasingly intersect with contemporary digital platform politics. As commercial platforms consolidate infrastructural power by controlling protocols, access points, and data flows, CNs offer situated alternatives through which governance, participation, and control are continuously negotiated. From this perspective, CNs function both as technological experiments and as socio-political prototypes, challenging the platformisation of everyday life.

Hence, CNs emerge through situated struggles over connectivity,

shaped by local histories, material constraints, and political cultures. Turning now to a specific case study, Ninux.org, I show how the politics of openness is not a static ideal but a dynamic and contested field, continually reconfigured through practices of infrastructuring, negotiation, and care, as well as through the governance mechanisms that sustain CNs over time.

3. Governing Community Networks, Opening Infrastructures

Unlike large, centralised networks owned and operated by powerful third parties—such as the state or major profit-driven Internet Service Providers (ISPs)—CNs are typically established by and for local or regional communities (see Belli 2018). Their primary focus is not profit generation but addressing the collective needs of their participants and communities. Indeed, participants in these initiatives recognise that contemporary social, cultural, and economic life is increasingly co-shaped by information and communication technologies, particularly through the production, circulation, and control of data and knowledge. In their view, connectivity should enable the circulation of information and knowledge as commons.

These networks also explore innovative models of distributed governance, grounded in cooperation and sharing among a community of peers (ranging from a few dozen to tens of thousands), echoing the principles of commons-based peer production (Shaffer 2020). By empowering users with technical expertise, CNs not only ensure the sustainability of their projects but also foster a more engaged and digitally literate community, capable of actively participating in the network's governance, development and maintenance. The experiential learning dimension and user engagement aspect of this model are clearly articulated by participants themselves. For instance, one participant in Ninux.org reflects on their involvement with the community not as a result of prior technical expertise, but as a learning process fostered through collective participation and support:

> No, I'm not an engineer, but here [in Ninux.org] it is not the situation where you're alone, trying to do things. When you approach a community that teaches you all sorts of things, it is easy to learn. So, my interest in

> mesh networks depends on a series of events that triggered my curiosity. I became interested, I went [to the meetings] and I liked it. I did not understand anything at first, as when I went there it was like listening to someone speaking another language. And slowly, by insisting, I started to learn that kind of language. (Interview 3, participant in Rome)

As the interview excerpt makes clear, CNs do not merely provide an alternative mode of internet access; they also enact a different vision of how digital infrastructure can be governed and how users can participate in that governance.

Many CNs rely on highly decentralised mesh networking architectures (Akyildiz and Wang 2005) that enable peer-to-peer interconnection among devices—including routers, computers, smartphones, and other terminals—through direct Wi-Fi links. This technical configuration is intrinsically linked to the political governance of the network, which is intended to be horizontal, community-based and self-determined. While the political commitment to decentralisation may have been the initial catalyst for many community-driven network infrastructures, it is important to recognise that this motivation alone is not sufficient for expanding their reach beyond a small group of highly committed individuals. For these community networks to achieve significant growth and wider adoption, they must offer services (e.g., local hosting, applications, videoconferencing, web servers, broadcast radio, and other intranet services) tailored to the specific needs of local communities and perceived as comparable to—or ideally better than—those provided by conventional ISPs, especially in relation to privacy and data protection. As one participant in Ninux.org explained:

> You cannot define our services really as 'services,' in the sense that normally a 'service' implies that there is a supplier for these services. In this case, being completely self-managed, the services have emerged when people, who had a need to do something, put up a solution and offered it to others. So, early things that came out were services to communicate, then chat and do other stuff like file sharing; someone also started to implement a search engine that searches within the files of all hard drives that are around. (Interview 1, participant in Rome)

A defining characteristic of CNs is their commitment to user autonomy, digital literacy, and the protection of fundamental rights to communication and privacy. Unlike commercial ISPs that may restrict web navigation or

censor specific websites and content, many CNs are designed to uphold principles of 'net neutrality.' Local mesh networks are often framed by their developers and users as alternatives to the global internet, offering spaces of autonomy that resist pervasive surveillance—a consequence of privacy-invasive practices embedded in traditional online service providers. In this regard, scholars note that local mesh networks are often embraced as infrastructures of resistance against the surveillance capitalism endemic to mainstream digital platforms (Sinnreich et al. 2011). Accordingly, such infrastructures advocate for a more egalitarian and collaborative political framework, characterised by governance structures that emphasise symmetry, mutual collaboration, and active participation (Kostakis and Bauwens 2014).

This model prioritises a politics of openness grounded in shared decision-making and collective ownership, contrasting sharply with the more centralised, corporate-controlled structures that dominate much of the current internet landscape. Against this backdrop, CNs reveal a set of recurring governance features through which a politics of openness is performed in practice (see Albert 2013; Baig et al. 2015; Belli 2018; Shaffer 2020):

- Open communication: A cornerstone is transparency. Many CNs have embraced this principle by implementing open financial reporting. This includes publicly disclosing all expenses, equipment costs, membership fees, and other income sources, and often maintaining a public registry of operational relay nodes.
- User engagement: CNs often engage their communities to shape the network's design and management. This is achieved through non-hierarchical organisational structures and collaborative decision-making processes that prioritise discussion and agreement. While most communication occurs via email lists or instant messaging platforms, many CNs also organise regular in-person meetings. These meetings, held weekly or monthly, provide an opportunity for all interested participants and core volunteers to connect socially and address crucial operational matters. This approach fosters a sense of community ownership and ensures that the network's development aligns with the needs and values of

its community. For instance, in the case of CNs providing internet access in areas overlooked by traditional commercial ISPs, it is common to accommodate members' diverse financial situations, developing specific subscription schemes for unemployed individuals and students, with some even adopting a 'pay-what-you-can' model. Furthermore, many CNs extend their services by configuring their networks to provide free internet access to various community spaces such as cultural centres, public parks, squats, schools, municipal buildings, and healthcare facilities.

- Expertise development and digital empowerment: A significant challenge faced by community networks is the varying levels of technical expertise among users, which can potentially reproduce the asymmetric dynamics between clients and ISPs characteristic of the dominant internet infrastructure. Recognising this, CNs place a strong emphasis on enhancing users' digital and technical literacy. They focus on teaching and disseminating technical expertise and network management skills to their members, viewing this as crucial not only for the network's longevity but also as a pivotal way of enacting a politics of openness. This approach aligns with their broader goal of creating inclusive, citizen-centric networks.

Overall, the analysis of governance arrangements in the context of CNs highlights some of the conditions through which a politics of openness is enacted. In this framework, the members themselves are intended to be the 'architects' of their network's design and implementation. This process is oriented toward minimising the influence of corporate interests and relocating decision-making power in the hands of users. Consequently, it fosters an environment where creativity and collaboration thrive: the simple act of neighbours sharing bandwidth or engaging in technical activities for network maintenance has far-reaching implications. It has the potential to strengthen community bonds, promote self-sufficiency, and create spaces for democratic engagement within increasingly digitalised societies. Hence, CNs can be understood as more than technical infrastructures: they operate as 'sociomaterial platforms' (Burke and Wolf 2021) within which communities can purposefully engage with,

articulate, and address the issues that the infrastructure is designed to confront (e.g., democratisation of digital communication).

Here, the notion of sociomateriality recalls the need to recognise that the political and technical aspects of infrastructuring processes can hardly be dichotomised, and that—accordingly—a politics of openness in network infrastructures is mutually defined at the nexus of human participation and the technologies mobilised in infrastructuring. In other words, CNs can be framed as a sociomaterial platform enabling a politics of openness, where communities engage to overcome the centralisation of internet infrastructure ownership, the subordination of citizens' privacy to data control, and the general predominance of commercial and profit-driven web services, while centring their governance on a digital inclusion and community ownership framework.

While these characteristics, often central to the CNs' political framework, possess transformative potential, they also demonstrate inherent ambivalences. Indeed, even the most ambitious challenges to dominant governance structures are, at best, partial and contain within their conceptions and structures the very elements they aim to alter. In this process, prevailing governance arrangements and social structures are inevitably influential. Community networks, whether due to external factors or internal design, inherently contain ideological tensions from their inception. This is unsurprising, given that they develop within a socio-technical space of established power dynamics and binding regulatory frameworks. Such tensions do not warrant dismissal, but neither should they be overlooked. Rather, they call for a reflection on how openness takes shape materially within CNs. As the following section illustrates, technologies are not neutral supports but constitutive mediators that actively configure how openness is enacted and sustained in practice.

4. Free Software, Wireless Antennas, and Technical Expertise at Work in Community Networks' Politics of Openness

> Originally, I started attending the free software environment. The free software community, even though it was a very nerd community, much more tied to technical issues, was still interesting because within it there

> were reflections, such as what you can do with the software, who can use it, where, when or how. If I'm the one who builds the tool, I can do certain things. But if the tool does not exist, then this chance does not exist anymore. As someone said, who writes code, writes laws. And I learned this thing here through the free software experience. (Italian community wireless network activist interviewed by the author)

This quotation foregrounds a central aspect of CNs, namely the political commitments embedded in the collective development, modification, and use of the hardware and software components required for network operation. This work is framed by developers, maintainers, and users of CNs as a means of opposing the concentration of technological power in the hands of a few corporations or governments, and advocating for users' rights to regain control over the digital infrastructures and tools that organise everyday experience. As such, it constitutes a performative intervention in shaping the sociomaterial conditions under which a politics of openness can be enacted.

In this regard, it is worth noting that CN members often find satisfaction in materially engaging with the technology itself. They are captivated by the hands-on aspect of wireless networking, deriving fulfilment from addressing technical challenges, devising innovative solutions, and releasing them in accordance with the principles of the Free/Libre and Open-Source Software (see Kelty 2008; von Hippel 2017). This approach challenges the dominant relationship between software production and market dynamics, thereby creating new conditions for alternatives to the neoliberal model of software development and distribution (Schoonmaker 2007). The opening quotation also suggests that CN participants adopt a critical stance toward the socio-technical entanglement of technology and society, resonating with Winner's (1980) argument that artefacts have politics. Winner emphasised the importance of examining the inherent characteristics of technical objects, arguing that they can embody political properties. Winner proposed two ways in which technology's political nature manifests: firstly, when a specific technical design becomes a means of resolving community issues; and secondly, when certain technologies inherently align with or enable particular politics.

In the context of CNs, this perspective is crucial for understanding how a politics of openness is sociomaterially enacted. This enactment can be grasped by attending to how specific technological choices are

themselves politically charged. These technologies, mainly grounded in the counterculture of media activism (McCaughey and Ayers 2004), actively contribute to shaping the network's politics of openness, rather than simply serving predetermined technical ends. For instance, the decision to rely on free software, which often requires complex ad hoc customisation, represents the clearest example of how tools used in open infrastructuring interweave with a broader political terrain. This interrelation encompasses issues of freedom, digital rights, and participatory democracy within ICT developments.

The politics of openness is thus enacted through the mediation of material artefacts. The relevance of materiality as a generative dimension of socio-technical processes has been extensively addressed in STS, particularly within actor-network theory (see Callon 1986; Latour 2005). To understand how materiality shapes the politics of openness, we can emphasise that technologies are more than mere organisational elements; they are integral to the politics itself, shaping a sociomaterial arrangement in which human actors and technologies are mutually reconfigured. This constitutive entanglement is central to users' engagement in CNs: open infrastructuring emerges through the alignment of discourses, governance arrangements, and material practices of technical work. This generative relationship between participants and artefacts becomes especially visible in the installation and maintenance of wireless antennas (WAs), where technical practices intersect with situated forms of political participation and collaboration (Crabu and Magaudda 2018). WAs serve as a material interface between CN users and the network, propagating signals that enable connections among network members. These WAs cannot be reduced to their technical properties, since their installation and maintenance have direct consequences for collaboration, forms of community membership, and the governance of the network as a sociomaterial platform for a politics of openness. Participants must assume responsibility for WAs installed on their roofs, a commitment that carries both symbolic and material significance in the care of the collective open infrastructure.

As this participant in Ninux.org has argued:

> A tacit rule is that below every roof, below every node, below every antenna, there must be an active member of the community. This is because the network is being conceived as something that we do and then we put in common. You cannot imagine building up the network

> like: 'Oh well, I'll come to your house, and I install the antenna... and then everything will be ok and you will never have to worry.' The key issue is that, by joining the Ninux network cable that comes down from the roof, you are not just replacing the commercial ISP cable, and nothing more has changed for you. Behind this network there must be people who are aware of how the network works, and therefore there's this tacit rule that for every antenna, there must be a human head. (Interview 7, participant in Bologna)

This account underlines the significance of shared responsibility in the infrastructuring process. Antennas are not merely functional devices but represent a point of entanglement between users and the technical system—a site where participation, care, and politics converge. The participant's emphasis on the presence of 'a human head' below each antenna reinforces the view of infrastructure as not just installed but lived and co-maintained through ongoing participation.

Antennas can thus be understood as non-human agents that actively solicit engagement and support processes of subjectification within the collective. They materialise both a technical project and a political vision rooted in horizontality, responsibility, and infrastructural awareness. Although not all participants are expected to master the full technical set-up, they are required to engage with its basic functioning; thus establishing a specific interdependence between human and material components. This model of shared configuration may limit scalability, as onboarding new members requires time and effort, but it also reinforces a bottom-up model of governance and participation. In this sense, the material and symbolic presence of antennas plays a constitutive role in sustaining the politics of openness and the collective identity of activist-technicians within CNs.

5. Final Remarks

Building on Hartley et al. (2018), the 'politics of openness' captures the tension between openness as a normative commitment and its situated enactments within socio-technical practices. This chapter has expanded that definition by demonstrating, through the case of Ninux.org, how openness becomes a contingent accomplishment—configured by governance models, technical artefacts, and practices of maintenance

and care. In doing so, it shows that the politics of openness is less a prescriptive ideal than a processual achievement, continually negotiated within grassroots infrastructuring. By shifting the analytical focus from normative definitions to the situated practices through which openness is made actionable, the chapter has contributed to a sociomaterial understanding of infrastructural politics—challenging the dichotomy between the political and the technical and advancing a relational approach where technical choices, governance models, and collective imaginaries are mutually constitutive.

The analysis has shown that CNs enact a politics of openness not through abstract commitments but through concrete practices of infrastructuring—designing, maintaining, and governing the network in ways that decentralise authority, cultivate shared responsibility, and foreground collective learning. Practices such as installing wireless antennas, customising open-source firmware, or co-managing routing protocols are not just technical operations; they contribute to the socio-technical construction of the politics of openness, embedding values of transparency, autonomy, and mutual care into the very materiality of the network. In this sense, CNs do not merely offer technical alternatives to centralised infrastructures; they constitute prefigurative infrastructures—spaces where alternative forms of socio-technical order are prototyped, contested, and iteratively negotiated.

Within CNs, openness emerges as neither a stable property nor an unproblematic goal. Rather, it is a doable problem—an ongoing accomplishment shaped by tensions between accessibility and complexity, inclusion and expertise, horizontality and coordination. These tensions are not simply challenges to overcome; they are generative forces that shape how openness is configured and contested in everyday infrastructuring work. The chapter has thus approached openness not as an inherent good, but as an emergent and situated achievement contingent upon specific sociomaterial arrangements. Moreover, the concept of CNs as sociomaterial platforms has been developed to capture the entanglement between human actors and technological artefacts in the enactment of openness. This conceptual move foregrounds how infrastructures are not merely supports for action but mediators that shape political subjectivities, redistribute agency, and organise

participation. Technologies such as wireless antennas and open-source protocols are not passive instruments, but constitutive elements in the network's political ecology.

Through their affordances and constraints, they channel particular modes of engagement, foster collective responsibility, and delimit the possibilities for democratic experimentation. At the same time, this chapter has also pointed to the ambivalent character of CNs. While they carry significant transformative potential, they remain embedded within broader socio-technical systems marked by power asymmetries, regulatory constraints, and infrastructural inequalities. CNs do not operate in a vacuum; their politics of openness is always partial, situated, and marked by internal tensions.

These initiatives must navigate the friction between their aspirations and the realities of maintaining sustainable infrastructures within a deeply commercialised digital landscape. Overall, this inquiry has shown that the politics of openness implies a continuous negotiation between ideals and materials, between practices and imaginaries. Openness, as enacted in CNs, is not simply about making things accessible or transparent; it is about reconfiguring the very conditions under which participation, knowledge production, and infrastructural agency become possible. By centring this processual and relational view, the chapter offers a critical lens for understanding how grassroots infrastructures do more than connect—they compose alternative forms of political life in the digital age.

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13. From Permacomputing to Agbogbloshie: Open-Knowledge Infrastructures for Computational Repair

Cyrus Khalatbari

Introduction

Our daily interactions are shaped by tech corporations using the socio-technical agenda of seamlessness (Ratto 2007; Black 2020). The pursuit of seamlessness obscures the human, material, and environmental infrastructure behind 'the digital.' It is embodied through minimalist User Interfaces (UI) or Experiences (UX) that prioritise connectivity and produce 'jittery-schizoïd intervals' (Greenfield, 2017: 40), shifting our perception of time. This desire for fluidity relies on a plethora of hardware that enables computational power: from local machines to routers, modems, and undersea cables, among others. In addition, the corporate agenda of seamlessness relies on the hidden labour of engineers, moderators, technicians, and users, optimising, maintaining, and recycling the network. In order to disentangle the material and human infrastructure hidden behind seamlessness and our digital interactions, the chapter focuses on alternative collaborative design practices and makerspaces.

Informed by fieldwork, the chapter takes the form of a comparative analysis between two arts and design communities mirroring across

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different cultural and geopolitical contexts. The first community, operating from Amsterdam (the Netherlands), is known as permacomputing: a portmanteau word formed by the association of permaculture and computing. The group aims towards the collective desire of fostering computational sustainability and resilience. The second federates around makerspaces in Accra (Ghana). As responses to the toxic afterlife of electronics, they provide tools and training to local communities. In placing in dialogue these two design communities, this chapter argues for three main points. First, it posits that studying these practices are essential in making tangible our computational and internet material and human implications, too often obfuscated by corporate tropes and their focus on the digital. Second, it argues that, while technology is regularly framed as planetary and universal, zooming in at the level of these two communities and the local scales in which they operate brings forward the situated nature of our interactions. Third and finally, the chapter argues that challenging techno-utopian narratives of net neutrality and tracing the evolution of these two communities reveals not only power dynamics enforced on consumers by corporations but also forms of resistance undertaken by independent arts and design communities. Drawing from these three sections, this contribution argues that 'seamfulness' and the openness of socio-technical systems emerge through distributed innovation, knowledge, and power enacted by communities of individuals and users—as forms of agency that operate largely outside of institutionalised computer science frameworks and challenge dominant corporate and techno-utopian narratives.

Ecomedia Studies

The chapter bridges two academic interests that are, through design and technology, inherently linked yet too often disconnected: science and technology studies (STS) and human–computer interaction (HCI). To challenge the narrative of technological immateriality, the theoretical framework draws on insights from the emerging field of ecomedia studies. The field aims to explore the environmental entanglements of computing by zooming in on specific objects powering our digital culture. Combining fieldwork with theoretical inquiries, authors of the field shed light on the material and environmental seams (Ratto 2007)

that power, maintain, and structure the digital objects of our daily lives. Whether from substrates like plastic (Davis 2015), tin (Ingulstad, Andrew, and Espen 2014), rare metals (Vikström 2017), or objects such as internet cafes (Burrell 2012), undersea cables (Starosielski 2015), or semiconductors (Lenny and Markoff 1985; Gabrys 2011; Rella 2023), these works shift our understanding of technology away from its private-based discourses of immateriality and digitality (Negroponte 1995).[1] Within HCI and critical design communities, this desire to reveal the materiality of media connects with two design propositions and postures: zombie media[2] (Hertz and Parikka 2012) and *numériques situés*[3] (Nova and Roussilhe 2021). Performing through design what Bowker coined as infrastructural inversion (Bowker 1994), they creatively and critically reappropriate materials and components that constitute our internet's hardware layer. While tropes around digitality overshadow the role of these devices, zombie media aims to create assemblages where old and new systems intertwine—questioning in turn the corporate incentive of planned obsolescence[4] and new media. With *numériques situés*, the focus shifts towards understanding digital technologies as embedded in specific terrestrial, environmental, and energetical contexts that power them and act as sites of executions (Howse 2014).

In arguing that studying these two contexts resists tropes of computational universality, the chapter builds on academic works approaching design as being bound to its local and material contexts. Extending from Mauss' embodied techniques (1973) and Haraway's 'situated knowledges' (1988), this framework foregrounds the ways in which bodily practices and epistemologies are deeply embedded within specific social, cultural, and material contexts. With the work

1 Nicolas Negroponte, a key figure of the Silicon Valley and director of the MIT Media Lab, in 1995 prophesied the shift towards digitalisation and technology in terms of 'bits replacing atoms' (2005), considering computing technology as weightless and non-materially-situated.

2 Zombie media is a term coined by Hertz and Parikka (2012), used to describe obsolete or discarded technologies that are brought back to life through reuse, artistic intervention, or critical reflection, exposing their hidden material and cultural dimensions.

3 *Numériques situés* (literally, 'situated digital'), taken from Nova and Roussilhe (2021), refers to digital tools and media that are embedded within specific social, cultural, and physical contexts, emphasising their local and contextual use.

4 Planned obsolescence is the deliberate design of products with a limited lifespan to encourage frequent replacement and sustained consumer demand.

of feminist scholars such as Suchman (1987) or Rosner (2020), the positionality of designers is brought into focus as a critical factor in the shaping of technologies and design practices. This shift challenges dominant narratives of objectivity in design and calls for the role of tacit knowledge and practices in understanding how technology is shaped, maintained, and activated by local and peripheral communities.

At the level of HCI, this aim is also advanced by critical making (Ratto 2011) and unmaking (Gaboury 2018), in which critical technical practitioners do not simply produce artifacts but develop critical awareness of technology within their local scales of action. Through these practices, the materiality of design, and our socio-technical culture are then disentangled in a situated and relational way. Outside of a techno-solutionist (Morozov 2014) approach in which devices aim towards exponential streamlining, making and unmaking serve to un-sanitise and re-politicise technology by unravelling its ecological seams and making it tangible, breakable, and reconfigurable. This practice reclaims agency over the corporate black-boxing (Latour, 1999) of our technological systems, inviting through situatedness a critical engagement with technology and its socio-material implications.

The chapter also draws on the STS concept of knowledge infrastructures and the way knowledge production can be used to better understand friction, conflict, resistance (Karasti et al. 2016), or enclosure within our technological cultures. Inspired by Star and Bowker's work on classification systems (Bowker and Star 1999), the concept developed by Edwards (2010) zooms in at the level of people, artifacts, institutions, and practices that enable the production, sharing, maintenance, and transformation of knowledge over time. Whether in the context of 'fab labs' and repair cafes (Jackson 2019; Madon 2021) or the broader hacker culture (Söderberg and Maxigas 2022), it provides a fruitful lens through which we can investigate the role of alternative infrastructures of knowledge powered by DIY and DIWO[5] approaches in fostering innovation, resistance, and artistic reappropriation.

Overlapping with previous design frameworks of critical making, zombie media, and *numériques situés* that aim for seamful design

5 DIY (Do It Yourself) and DIWO (Do It With Others) refer to individual and collaborative modes of making, often linked to grassroots innovation and maker culture.

(Ratto 2007), this desire to bring forward alternative socio-technical configurations and imaginaries (Jasanoff 2015) strongly resonates with DiSalvo's adversarial design (2015). Building from Mouffe's concept of agonistic pluralism (1999), adversarial design foregrounds contestation and dissensus as essential to democratic engagement, positioning design as a space where conflicting worldviews can be articulated, negotiated, and made visible through material forms. In this context, the production of design and technology is displaced from the quest for efficiency and streamlining. While initially designed for enclosure and control, it is reappropriated to make visible and disrupt the dominant narratives it embodies, opening up spaces for critical reflection, debate, and more sustainable futures.

Materials and Methods

In addition to observation diaries, both case studies of permacomputing and Accra's makerspaces are composed of semi-structured interviews with community actors met on site or online. The author of this contribution is external to both communities. Although the author is culturally closer to permacomputing since he is based in Switzerland and conducts research with European-based art and design institutions, he developed long-term relationships with Accra and Agbogbloshie through artistic collaborations with designers, engineers, and artists.[6] The author participated in two workshops and fieldwork in Amsterdam and Accra and conducted interviews online. The fieldwork on permacomputing first took place during two intensive workshops that ran for two days each and were organised by the cultural institution FIBER (Amsterdam, the Netherlands, 13 and 14 October; 30 November and 1 December 2023). In their *Reassemble Lab 5: Practising Permacomputing*,[7] participants explored sustainable approaches to computational culture by combining hands-on experimentation with critical discussion. The lab brought together artists, designers, technologists, and researchers

6 Amongst others, collaborations occurring during the Ars Electronica/STARTS+ artistic program: https://ars.electronica.art/hope/en/events/into-the-e-metropolis/

7 The program of the lab can be accessed here: https://www.fiber-space.nl/project/permacomputing/

to collectively question dominant paradigms of efficiency and growth in computing, and to investigate alternative, low-tech, repair-friendly practices. Across these two workshops, more than ten interviews were conducted with participants and facilitators ranging from designers, artists, and engineers. The fieldwork in Accra and its makerspace communities took place over a full week (1–8 January 2023), and then at irregular intervals between January 2023 and May 2025. Over this period, more than ten interviews were conducted. Profiles of interviewees range from community organisers, architects, and designers to nearby workers (maintainers, scrap-dealers, dismantlers, burners). Two makerspaces are the focus of the study. The first is the Agbogbloshie Makerspace Platform (AMP), developed by architects and scholars Abbas and Osseo-Asare. AMP, based in Agbogbloshie, emerged as an international network of designers, activists, and researchers operating at the intersection of local practices in Ghana and collaborations with global institutions. Following the first demolition of the site in 2021, AMP reconfigured its activities into more distributed forms, redefining its vision while developing a more adaptive and resilient operational model. The second is Innovate Labs, founded in 2021 by Accraian designers and consultants Freda Yawson and Prince Nana Kow Essel. While not based in Agbogbloshie, Innovate Labs grew in more commercially oriented ways, offering services and access to prototyping tools to local designers and companies. Inspired by AMP, Innovate Labs also acts as a social actor of the circular economy, engaging with Agbogbloshie communities through workshops and collaborations.

Grounded Contexts of Computation

Permacomputing

While tech corporations depict the internet as immaterial through minimalist design choices and streamlined platforms, investigating design communities' local scales makes tangible the material and human infrastructural implications of our digital practices. Resisting these corporate tropes in which the internet is framed as a weightless, placeless, and ephemeral data transmission cloud, designers—through their critical practices of making and unmaking—contribute

to further making visible and tangible the environmental materialities that underpin our digital life. This desire sits at the core of the permacomputing model: inspired by the permaculture movement and its land management approach aimed at working with, rather than against, nature (Mollison 1991).

As articulated in the movement's principles (see Figure 13.1), the linkage to permaculture first appears through its emphasis on temporality: embracing long-durational processes and a frugal approach deemed essential to foster the development of more sustainable computational ecosystems. In order to resist the injunction for new media and brainstorm on alternative ways of embracing technology, old devices are repurposed. Amongst its propositions, this resonates with a *care for life*, a *care for the chips*, and *the need to build on solid ground*, as a:

> critique of contemporary computer technology that privileges maximalist aesthetics where more pixels, more frame rate, more computation and more power equals more potential at any cost and without any consequences. (Mansoux et al. 2023: 1)

In similar ways to the ecomedia studies' need to focus on 'stuff you can kick' (Parks 2015), the reinvestment of these old computers materialises what is too often overlooked by corporate tropes on the digital. As put forward by Mansoux and colleagues, this urgency to *expose everything* is driven by the need to shift from

> a static understanding of infrastructure to a more dynamic one that adapts to changes in the local environment. (Mansoux et al. 2023: 9)

Echoing zombie media (Hertz and Parikka 2012) and *numériques situés* (Nova and Roussilhe 2021) in which digital processes become grounded in hardware and become visible in terrestrial ways, this relational approach of permacomputing materialises in the solar protocol[8] project (2024). The project is a solar-powered, distributed web hosting network that prioritises server access based on sunlight availability, making computation responsive to planetary rhythms and its environmental factors. While tech corporations obscure the energetic dependencies and infrastructural demands powering their services, the project foregrounds these material realities—connecting computation to

8 The solar protocol project can be found here: https://solarprotocol.net/

the contingencies of weather, geography, and energetics. In doing so, it challenges dominant narratives of seamlessness and efficiency, offering an alternative model in which the digital is made dependent on, and entangled with, the tangible, terrestrial nature of computation.

Fig. 13.1 Server infrastructure of the https://solarprotocol.net/, powered by solar electricity. Source: Solar Protocol.

Agbogbloshie

Mirroring permacomputing, observing local scales at play within Ghana's capital fab labs also makes tangible the material entanglements of digital technologies—their dependencies on hardware infrastructure, energy, labour, and localised forms of repair and innovation. Nuancing corporate tropes of digital immateriality, focusing on these Ghanaian makerspaces helps disentangle the transformative journeys of materials, tracing how discarded electronics are dismantled, repurposed, and reimagined into new objects and contexts. In order to trace this infrastructure, it is important to investigate the relationships between the makerspace users and the nearby workers and scrapyards. The site of Agbogbloshie, in particular, is central, operating as an informal recycling and innovation hub (Potter et al. 2019). In this context, an Innovate Labs member and local designer states:

> When I need computers, I either go to burgers or maintainer's shops. But when I need spare parts, I go to Agbogbloshie. Capacitors, components, and other ICs. I have a network of dismantlers that pile non-functioning

> computers bought from the city's technicians. I can then source things I want to replace or need when working on my PCs. (Makerspace educator, Accra, 2025)

At the point where computer-device processing chains diverge from the activities of Ghana's urban miners (Grant and Oteng-Ababio 2016), the first community the designer identifies is the group known as the 'burgers.'[9] Part of the Ghanaian diaspora, this community supplies electronics to the country, acting as intermediaries between countries of the Global North—where computers are regularly discarded due to planned obsolescence—and Ghana's local markets. Bought untested, 'burgers' work with maintainers to assess, repair, and repurpose the devices they import. Maintainers provide the expertise to diagnose faults, replace components, and restore functionality. They then sell the fixed devices in nearby markets or shops. A third category of workers unravelling modern technology's material and human infrastructure is that of dismantlers. As mentioned by the designer and makers, dismantlers—unmakers—are inherently linked and interdependent, revealing the circular economy of computer recycling in Ghana. Maintainers rely on dismantlers for components used in repairs, while dismantlers depend on maintainers for condemned[10] computers from which metals can be extracted. Finally, a fourth community, overshadowed by tropes of technological immateriality, is revealed in Accra's makerspaces: burners. These individuals and collectives—often working outdoors with improvised tools—carry out the final stage in discarded electronics' lifecycles. Through controlled combustion of wires, boards, and casings, they extract metals like copper and aluminium. As shared by an educator from Innovate Labs, the space provides a platform where designers and burners can collaborate on developing more sustainable methods:

9 The term 'burgers' refers to Ghanaian traders and importers of second-hand electronics, originally named after their connections to the Ghanaian diaspora community in Hamburg, Germany. The term has since extended to workers and traders operating in North America, Canada, Europe, and the UAE, reflecting the increasingly global nature of these transnational networks.

10 In Ghanaian slang, 'condemned' refers to second-hand electronic devices or appliances—often imported from Europe, North America, or Asia—that are no longer considered good enough to sell as new.

> In addition, we [designers] also help them [burners] to formally sort things and make the best of things that get processed. And because of toxic fumes that later affect them in life, we are trying to come up with machines for more sustainable burning options and practices (Makerspace educator, Accra, 2025)

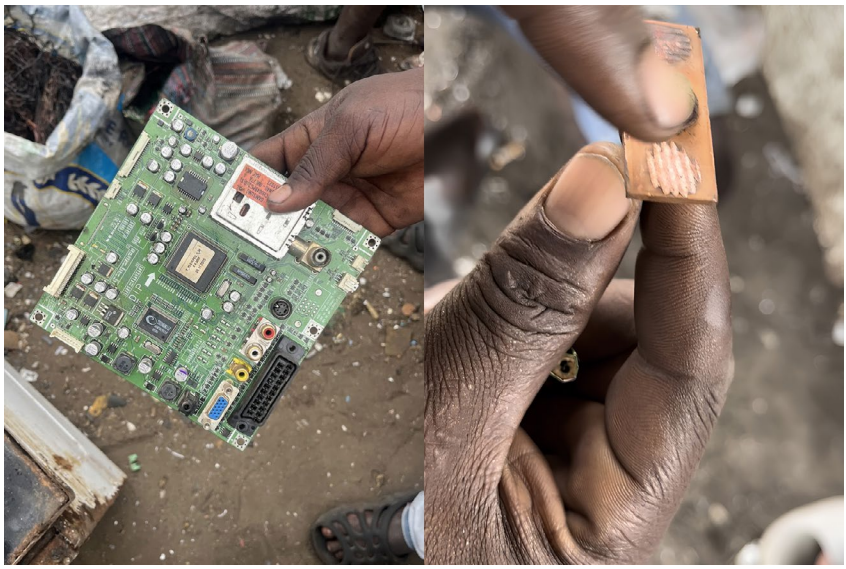

Fig. 13.2 A motherboard (left) and removed copper part (right), in which lines have been produced for assessment. Source: the author.

Zooming in at the level of permacomputing and Accra's makerspaces reveals the material and human implications of computing power and the digital. The two communities indeed widely differ. The participants of workshops held in Amsterdam are examining ideals on a project basis, to seek a new relation with technology by willingly accessing its tangibility. By contrast, the workers of Agbogbloshie make their living by iterating with the metabolites of discarded technologies, a practice that inevitably exposes their bodies, and at times endangers their health. Still, there is a mirroring socio-technical context: both environments resist corporate tropes of technological immateriality and re-ground digital interactions in hardware, energetics, and raw materials. From the use of old devices to speculative projects like the solar protocol, *permacomputing* foregrounds low-tech, energy-aware, and maintenance-driven approaches that make visible the infrastructural costs of

computation. In pursuing collaborations with local communities of the Agbogbloshie scrapyard, Accra's makerspaces similarly surface the human and environmental afterlives of digital technologies. Together, these practices help render tangible the invisible circuits of extraction, repair, and survival that undergird the digital, offering counterpoints to dominant narratives of digital progress and the so-called internet cloud.

Computational Culture and its Situated Practices

By resisting narratives of technological universality put forward by corporations through their standardised design choices and platforms, these two contexts reveal a more nuanced and situated (Haraway 1988) understanding of computing. By tracing the specific embodied practices found in each context, dominant assumptions about computing as a global technology can be challenged and highlight the way it is used and reappropriated by communities in context-driven and culturally specific ways. This perspective resonates with the principles of permacomputing, which foreground resilience, adaptability, and local resourcefulness as alternatives to global models based on extractivism and the injunction of growth. Beyond the reliance on planetary-scale computing infrastructures and the monopolies of Big Tech corporations, the permacomputing movement advocates for building devices and communication systems at smaller, more localised scales as a critical step toward more sustainable and context-sensitive engagements with media. This posture has been motivated by members' awareness towards the interference of corporations in hackers' communities and the risk of scaling up:

> To avoid repeating past mistakes of the FLOSS where initial political goals were not achieved due to institutionalisation and the inclusion of broader structures driven by corporate agendas, we operate in a more rhizomatic and distributed way. (Engineer, FIBER permacomputing workshop, 2023)

In order to operate in such a way—driven by the 'keep it small and keep it flexible' motto—the community centres around workshops. Inviting people to bring diverse electronics to the table, practices of critical making (Ratto 2011) and unmaking (Gaboury 2018) are then utilised to scan and assess new usages for these miscellaneous

discards. Driven by exploratory, open-ended, and horizontal models of knowledge sharing and production, members practice co-design, DIY, and DIWO techniques. Revisiting the community's shared pads and wikis where tutorials are freely made available, computers are opened to produce small networks in which situated practices of computing are favoured. Once the open-source Linux kernel and its distros[11] are installed, members aim to develop local servers, private file sharing, or alternative social media and forums operated at the smaller scales of their devices. Through these local gestures—repairing, repurposing, and reconfiguring discarded electronics—the community not only enacts situated practices of computing but also reinvests the materiality of computation with renewed meaning, resisting abstract, universalising tropes of digital culture by grounding technological engagement in context, care, and collective experimentation. In doing so, designers reclaim agency over technological systems, transforming computation from an invisible, ubiquitous, and seamless utility into a tangible and culturally embedded practice.

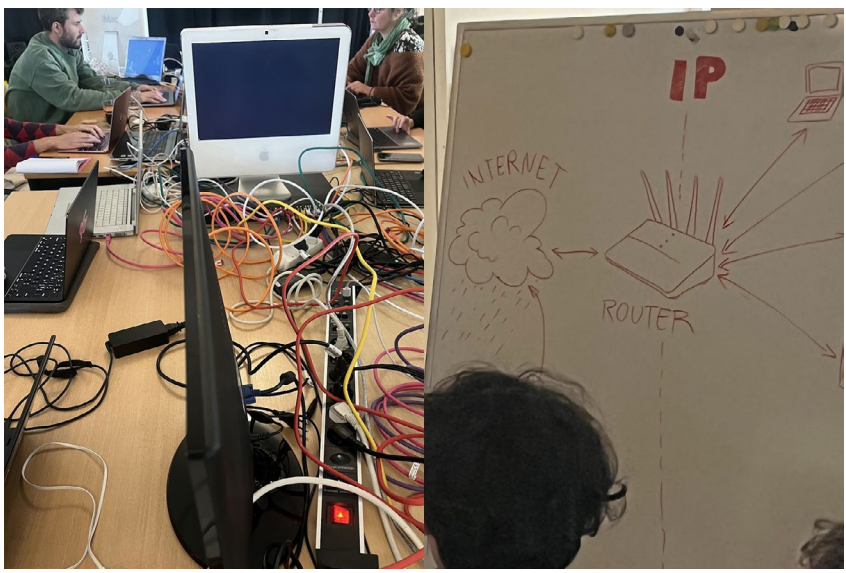

Fig. 13.3 Permacomputing explorations at FIBER, Amsterdam. Source: the author.

11 Short for 'distributions'; commonly refers to different versions or variants of the Linux operating system, each with its own package management, default software, and configuration tools (e.g., Ubuntu, Fedora, Arch Linux).

Exploring Ghana's capital makerspaces, in line with the situated practices advanced by artists and designers within the permacomputing framework, reveals alternative understandings of computing that challenge the dominant corporate narratives of global interconnectedness. Rather than focusing on disembodied visions of technology, such initiatives further reveal the way maintaining and recycling infrastructure is inherently tacit, subjective, and context-specific. Articulated by Potter, Osseo-Asare, and M'Rithaa, this is central in articulating the AMP and its goals through:

> an engagement with indigenous R&D and a commitment to the idea that problems on the African continent are better tackled using transdisciplinary, co-design methods that prioritise local stakeholders and African design solutions. (Potter et al. 2019: 50)

As mentioned by designers Osseo-Asare and Abbas, the Agbogbloshie scrapyard—as a district of Ghana's capital—serves as the key site from which to contextualise and trace the emergence of these embodied and local practices of maintenance and recycling. In addition to its role in supplying designers and maintainers with the necessary components and devices, studying communities of dismantlers, scrap-dealers, and burners operating on site contradicts Western visions of the 'e-waste dump' (Yeebo 2014). Rather than a static landscape of pollution and neglect, Agbogbloshie emerges as a dynamic socio-technical environment where informal expertise, tacit knowledge of repair, and embodied techniques of recycling emerge. These practices reframe the narrative around electronic waste, revealing a situated network of creativity and innovation that challenges reductive representations and invites more nuanced understandings of technology and its flows. As described by one of the Innovate Labs members:

> workers don't have a collective knowledge they can both connect to. All of them have specific techniques they learn from the field or by working with skilled workers they undertook their apprenticeships with. (Makerspace member, Accra, 2025)

The cultural embeddedness of the technology also becomes evident as we follow the journey of raw materials through local networks of craftsmen and recyclers. In this context, aluminium sand-casters exemplify how technical knowledge is grounded in local practices,

operating at the scale of small workshops where artisans develop techniques to melt aluminium in homemade furnaces and transform scraps into cooking pots and other kitchen equipment. While the digital lifecycle is largely portrayed by corporate narratives as being seamless and linear, following the elemental implications of these devices reveals how technology 'does not really follow the logic of from life of use to death of disuse' (Parikka 2015: 48). These processes represent a form of grassroots and circular engineering that contributes to a broader, situated way of knowing through making—one that is inseparable from the socio-material environments and communities that sustain it.

Fig. 13.4 Aluminium-casting workshop, where discarded electronics are burned and transformed into cooking-pots. Source: the author.

Investigating permacomputing and Accra's makerspaces exposes the situatedness of computational culture and its interdependence on actors often overshadowed by dominant tropes. Expanding from the first argument, these two communities further help render visible—and tangible—how, beyond corporate strategies for technological seamlessness and standardisation, the socio-technical fabric of technology is disentangled in local, context-driven ways. In permacomputing, this materialises in community-led DIY and DIWO

strategies that highlight solutions to circumvent and resist planned obsolescence and Big Tech monopolies. Inside Accra's makerspaces, this takes shape in the role of Agbogbloshie, fostering innovation and supporting local circular economies. Collectively, they broaden our understanding of technological innovation, shedding light on embodied techniques, localised knowledge, and diverse practices that challenge dominant paradigms of design and production.

New Imaginaries of Resistance

In addition to the circularity and situatedness of our computational culture, studying arts and design contexts structured around permacomputing and Accra's makerspaces reveals both exertion of power by corporations over consumers, and the ways independent arts and design communities resist or subvert these dynamics. Throughout the field, this asymmetrical power dynamic and agonism (Mouffe 1999) emerges from technological systems exponentially harder to decrypt and repair. Amongst members and workshop participants, this materialises in the desire to reinforce technological literacy and bring forward more sustainable embodiments of technology that counter the monopoly of Big Tech and their politics of enclosure. By foregrounding low-tech, frugal, and ecologically sensitive practices, the field does not only aim to extend the life of digital materials but also reinvest computing as a medium to foster critique and awareness. As articulated by a workshop member:

> My motivations? I want to teach my kids to be critical towards this slightly dystopian extractive process we are all tied to. (Artist, FIBER permacomputing workshop, 2023)

As a catalyst for critique and speculation, permacomputing's emphasis on smaller scales is critical. This focus offers members the opportunity for seamful design (Ratto 2007), in which the material and environmental seams of technology are intentionally made visible and used creatively. Expressed in the following words of a participant and artist member, behind this quest for a more sustainable practice lays in turn the desire to detour (de Certeau, 1984) and playfully invest what is hidden behind our digital practices:

> I was working on a project tackling issues about technology and its environmental implications. I was writing the text on my computer, and I suddenly thought: what an irony to talk about nature in front of this plastic box that connects to a highly complex extractive industry. I therefore wanted not just to talk about nature but physically interact with it. Go in the woods, smell the grass, feel it. (Artist, FIBER permacomputing workshop, 2023)

Beyond the repurposing of discarded devices for new design applications, participants also engage in more radical and polysemic approaches. These gestures give rise to playful assemblages in which organic, industrial, and digital material regimes entangle—opening up speculative visions for alternative technological futures.

Fig. 13.5 Permacomputing explorations at FIBER, Amsterdam. Source: the author.

Mirroring the permacomputing community, studying practices of art and design occurring in and around Agbogbloshie also helps bring to light asymmetrical power dynamics as well as acts of resistance. When investigating workshops and research undertaken by makerspaces such as the AMP or Innovate Labs, a central example of labour injustice unfolds in the way computers are miniaturised, resulting first in a discrepancy in precision tools. These devices, increasingly complex and compact, require advanced equipment and expertise to dismantle

or repair—resources that are often inaccessible in informal or under-resourced settings. In response, makerspaces offer maintainers access to more advanced soldering and repair stations. Another struggle workers contend with is due to the miniaturisation of chips connected to the use of hazardous techniques—fire, acid baths or crude mechanical methods—which they have to dismantle and extract valuable metals. With motherboards and PCBs exponentially shrunk, components are more densely packed and often soldered with materials that are difficult to separate. As one dismantler in Agbogbloshie explains:

> You see that line there, on the board? If you burn it, then you will have fresh copper. Right now you don't see anything, because brands put polish on it. But if you burn it, all the paint goes out and the copper will remain…Then you just use your hands, and pull all the copper from it. (Dismantler, Agbogbloshie)

In parallel with the principles of permacomputing, forms of resistance often emerge through the development of collaborative infrastructures that facilitate engagement between workers and designers in workshops and training programs, enabling the co-production of knowledge around more sustainable recycling practices. Additionally, another form of friction and adversarial design (DiSalvo 2015) arises from the work of Ghanaian artists creatively repurposing these discarded parts. In close contact with these makerspaces' communities, the inter-manipulated (Osseo-Asare and Abbas 2015) approach of these devices is further investigated, shifting hardware modification into sculptures and installations, questioning tropes of planned obsolescence and these objects' afterlives. In the work of Akwasi Bediako Afrane,[12] a Ghanaian artist based in Kumasi, electronic devices found in local markets become raw material for the production of 'T(H)RONS' (Afrane 2024), in which alternative socio-technical imaginaries (Jasanoff 2015) are enacted through the reconfiguration of discarded technologies. Like micro-organisms breaking down and reconfiguring in alternative ways, Afrane's practice repurposes new meanings to the dead objects of the landfill—transforming them into autonomous and polysemic entities that challenge the dominant notions of obsolescence and electronic 'waste.'

12 The work of Akwasi Bediako Afrane can be accessed here: https://www.instagram.com/afranemakof/?hl=en

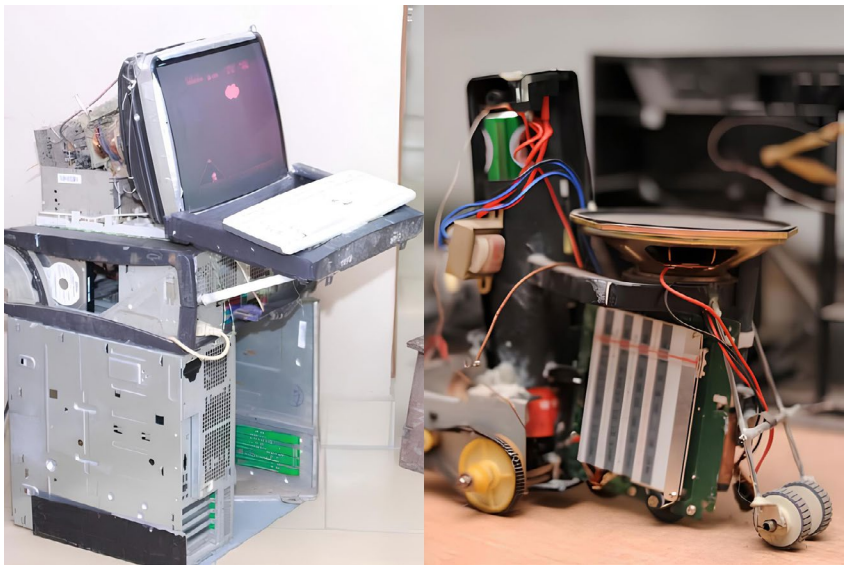

Fig. 13.6 Akwasi Bediako Afrane's AP-T (left), 2016, and T-2 (right), 2017. Source: Akwasi Bediako Afrane.

From permacomputing and Accraian makerspaces, community struggles and vertical labour dynamics along processes of planned obsolescence and chip miniaturisation manifest. Through the analysis of friction, conflict, and resistance (Karasti et al. 2016) within these communities, exploring these situated practices of resilience helps disentangle how tech corporations enforce, through design, specific socio-technical configurations and labour forces. In permacomputing, this appears as a reaction against extractive technologies and Big Tech monopolies, driving a need to operate beyond academic institutions through more distributed approaches. While computer-science and engineering programs sustain industry logics, these community-driven practices foster a necessary 're-politization' (Hertz 2020) of technology. In Accra's makerspaces, struggles emerge from miniaturisation and its design choices, reinforcing corporate control and obsolescence. Through tools, workshops, and collective knowledge, the AMP and Innovate Labs leverage design as a political and agonistic (Mouffe 1999) force for openness, empowerment, and sustainable recycling. In creatively repurposing technological seams, both communities subvert embedded material politics, transforming constraints into spaces for autonomy and alternative socio-technical imaginaries.

Seamfulness as Knowledge

Both communities operate from culturally different standpoints, which in turn shape how they relate to electronic waste and engage with the global issue of planned obsolescence. In both Amsterdam and Accra, struggles are observed. For permacomputing, contradictions stem largely from the socio-economic status of its members: participation is often a matter of choice rather than necessity. Members attend workshops, discussions, and experiments not because they are compelled to reuse or repair, but because they seek to explore alternative computational paradigms and socio-technical imaginaries (Jasanoff 2015) through intentional engagements with discarded technologies. This initiative contrasts with contexts like Accra and its makerspaces, where repair, reuse, and dismantling are often economic imperatives rather than speculative or aesthetic gestures. Out of economic pressure and the incentive of profit, hazardous methods such as plastic burning are still widely used. These two sites, however, mirror in three main ways. First, they posit that studying these practices as new 'situated knowledges' (Haraway 1988) is essential in making tangible our computational and internet material and human implications, too often obfuscated by corporate tropes focused on the digital. Second, they show that, while technology is framed as planetary and universal, local scales reveal the situated nature of our interactions. Third, they reveal how corporate power dynamics lead to resistance by independent arts and design communities supporting openness and challenging techno-utopian narratives of net neutrality. Ultimately, placing these two fieldworks in dialogue invites us to rethink computational futures not as inevitable outcomes of globalised techno-economic forces, but as contested, negotiated, and culturally situated practices. In doing so, it opens space for alternative trajectories of innovation located outside computer science and engineering institutions. In leveraging the role of art and design to support communities towards alternative practices that foreground sustainability, seamfulness acts as a vital counterpoint to depoliticised visions shaping and structuring day-to-day life. This contribution argues that the openness of socio-technical systems emerges through distributed innovation, knowledge, and power enacted by communities of individuals and users—as forms of agency operating largely outside institutionalised computer science frameworks and challenging dominant corporate and techno-utopian narratives.

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14. Controversial Openness, an Exploration of Open Image Generation Assemblages

Nicolas Malevé[1]

Introduction

Synthetic images are produced at a dizzying scale (Valyaeva 2023a). AI image generation software has become an infrastructure on top of which other products are built. If AI can be compared to electricity, as machine learning pioneer Andrew Ng once put it (Lynch 2017), synthetic image production fulfils an infrastructural function for a gamut of products used in domains such as film production, news or telescopes and is increasingly used by social media users for entertainment purposes or political debate. In these contexts, generative AI provides visual understanding and production on demand.

Many problems have been identified in AI image production ranging from racist, sexist, and otherwise stereotypical representations (Offert and Phan 2022), to privacy infringement (Walsh 2024) and cultural misappropriation (Milmo and Hern 2024). In these pages, I will focus on another key problem: the concentration of decision power and capital accumulation in the hands of a few global companies (Kak, Myers, and

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Whittaker 2023). This problem is aggravated by the increasing collusion of platforms and state power as demonstrated in the large-scale investments by international actors such as the US or the EU (Swinhoe 2025; Parvini 2025). This issue emphasises the need for critique as well as the exploration of alternative scenarios. This text is written in the perspective of a potential transformation of AI, to better understand how various practices attempt to challenge the centralised accumulation of power within the constraints of platform capitalism. It examines how different projects and communities challenge the dominant platforms' centralised mode of production and the implications of these projects for governance, knowledge, infrastructure, and the redistribution of social relations and hierarchies that their open approach to infrastructure induces.

The chapter is distributed over three main sections. In the first, I use OpenAI to discuss its logic of centralised accumulation of power wherein the ownership of the material base is used to establish dominance. Dominance is achieved through a constant appropriation of external resources which relies on an elaborate practice of legal gaming. By studying OpenAI's use of software licensing, I argue that this very mechanism of appropriation opens them up to potential interventions. In the next sections, the chapter moves on to discuss two case studies that exemplify the opportunities offered by legal gaming in order to 'open' this infrastructure, exploring ways of decentralising it and testing the limits imposed by the material base. In contrast to OpenAI, I examine two projects that take up the challenge of submitting the infrastructure of generative AI (genAI) to a process of variation. Stability AI attempts to lower the dependency on hardware through a curatorial approach to data collection, testing the hypothesis that, with better data, one can provide a state-of-the-art image generation product. Stable Horde, a project run by a network of volunteers, builds on the products and models released by the former to create a distributed infrastructure for image generation where the material base is made of the personal computers of volunteers sharing their resources. Through the analysis of these case studies, I reflect on their implications for governance, knowledge and infrastructure, and the redistribution of social relations and hierarchies. This text is written from the position of a participant observer in these communities as a visual practitioner and educator. For three years, I have followed the technical development

of the software projects discussed in this study and the communities involved in their creation and maintenance. It has involved the close reading of legal documents, technical documentation, press material, blog posts, forums and hands-on testing and experimenting with code. To make sense of these case studies, I approach them from an analytical lens largely influenced by assemblage theory, whose emphasis on the processual dimension involved in the composition of socio-technical entities strongly echoes my experience of following and engaging with communities producing software.

Infrastructural Assemblages

A widely shared understanding of the term 'infrastructure' refers to a material base on top of which activities can be developed (Steinhoff 2018: 90). However, as Marina Vishmidt (2017) has theorised, an infrastructure cannot be limited to an actual material base, it also includes the traits, mechanisms and dynamics that secure its reproduction and form its future orientation. To borrow Bassam El Baroni's beautiful formula, infrastructures are transitional because they exist 'between the material and the possible' (El Baroni 2022: 33). As inherently relational, an infrastructure can be defined as an assemblage, an 'arrangement of heterogeneous parts' gaining affordance by entering into relation (Ohls 2022: 158). Its existence requires a constant work of composition and stabilisation. Therefore, to attend to the significant forms of relation that subtend an assemblage requires more than the exhaustive identification of its components. Following Deleuze and Guattari, Manuel De Landa (2016) argues that assemblages are characterised by a diagram, which can be understood as an implicit set of relations between a material base and agents under a number of constraints and possibilities. In line with De Landa, the chapter adopts a diagrammatic approach in that it attempts to map the relational layout of generative AI open infrastructures and to draw its centres of gravity and lines of flight. Further, the fact that assemblages are in a permanent process of composition has an important methodological consequence for thinking about the nature of alternatives and bifurcations in infrastructures. Rather than treating different infrastructures as distinct exemplars standing in opposition to each other, it encourages approaching the diverging infrastructural

assemblages under study as undergoing the exploration of a same space of possibilities with very different implications. To put it more simply, while acknowledging the differences between opposing hegemonic platforms such as OpenAI and its alternatives, I will consider them at the same time as variations of each other. Or in assemblage theory's jargon, I will consider them in terms of variations of a same diagram that contains the possibilities and constraints they all confront.

As an assemblage permanently involved in a process of composition, an infrastructure always presents some degree of openness. But if this is the case for all infrastructures, some of them are explicitly called 'open.' In this chapter, the meaning of the term 'open infrastructure' is inflected by the specific meaning it is given in computer culture to characterise code, platforms as well as standards, licenses and rights. It inherits its understanding from the struggles of the nineties where free and open-source communities fought to reclaim access to their means of production, which had been threatened by the increasing centralisation of the computer industry (Berry 2008: 98–100). In this context, open means that the software infrastructure is transparently offered for reading and writing. The inherent openness of any infrastructure is turned into both a political demand and invitation to participation and mutual aid. Further, openness is formalised through legal means to prevent predatory privatisation. In this specific qualification of openness, law, as we will see, is conceived as a privileged means to manipulate the infrastructural assemblage's diagram in order to regulate or subvert the relations of power that undergird it.

Knowledge Production and the Weight of Compute

To begin the analysis of generative AI infrastructures, let's start with the core component that structures their mode of production: the material base. The cost of state-of-the-art AI systems exponentially increased as the computer industry's major players engaged in an arms race over the last decade. In 2022, Openexo estimates that Google invested $30.7 billion in AI followed by Facebook and Amazon (Valdés Porras 2024). The firm Andreessen Horowitz reports that many companies spend

more than 80% of their capital on computing resources (Apenzeller, Bornstein, and Casado 2023). In 2023, the 'now next later AI report' evaluated the training cost for OpenAI's GPT-4 and Google's Gemini Ultra to '$78 million and $191 million, respectively' (Almeida 2024). These costs included the extraordinary amount of energy and water consumption that results in a substantial carbon footprint (McLean 2023). The expression 'compute divide' (Besiroglu et al. 2024: 1) designates the disproportionate need for computational power (or 'compute') in AI and its concentration in the hands of a few actors. The compute divide signals a context where the division of labour in AI research is determined by material ownership. As Besiroglu and colleagues (2024: 4) observe, the economic factor conditions who is in charge of the core tasks, such as the creation of large models. If hardware monopoly gives a few companies an uncontested advantage over their competitors, they combine their dominant position with a strategy of collaboration with academic and independent researchers whose terms they dictate. As a consequence, a majority of researchers work with open-source models released by the industry. Companies define standards for architectures and other settings 'in a way that pre-empts the development of competing standards' (Besiroglu et al. 2024: 5) Hardware monopoly induces a positionality: large companies work upstream and the rest work downstream. As models, code, and standards implicitly reflect the positionality of the infrastructure, those working with the industry's models always inherit the hierarchies embedded in them. This results in a situation where the academy tests and debugs industry's models, providing free labour to tech giants.

These observations give us the first elements of the diagram of relations that subtends generative AI infrastructure. Ownership of hardware is not simply a material asset; it is also a powerful means to establish the relations between the platforms and those who produce knowledge. The monopoly on computing capabilities works as an attractor that distributes relations of power. However, the control over the tangible assets such as the compute is not enough to sustain their infrastructural assemblage. A closer look at these power relations reveals the extent to which they are, in addition, legally coded.

Legal Coding of AI Platforms and Value Extraction

Far from the Microsoft strategy of the 1990s that revolved around intellectual property control, the AI industry strikes a balance between hardware dominance and partial source code distribution. Legal agility is as important for the AI industry mode of production as the monopoly over physical resources. OpenAI is a case in point. In its early phase, OpenAI, then a non-profit organisation, promoted openness as it needed to attract users and talent. OpenAI released its early models under an MIT license that allows anyone to use the software. Then came the phase of capitalisation of their assets. In 2019, OpenAI restricted access to its new algorithms and its services were only available through a commercial API. Since this moment, the source code was kept under wraps.

Legal coding introduces a degree of what legal scholar Katharina Pistor (2020) calls gameability. Legal gameability refers to the dimension of the law that enables strategies based on the relative indetermination of legal objects, the degree of interpretability that can be leveraged to push legal boundaries, and redistribute the cards among parties seemingly bound by an agreement. The legal construct allowing for the transition from an open-source model to a proprietary model is a good example of legal gaming: a 'permissive' license authorises the integration of open products into proprietary software without obligations or constraints in a spirit of market anarchy (Berry 2008: 172). In the case of OpenAI, this legal mechanism enabled the company to build on the efforts of communities of developers without 'giving back.' This legal form eases the transition from an open collaborative structure to a closed one. The value produced by the efforts of a multitude of developers unaffiliated to a company can be appropriated in further products.

However, legal gameability works both ways. The transition from one form of ownership to another always implies a residue that can serve to build an alternative. For instance, OpenAI's license change doesn't give it full control over the code that was produced when it was open source. If competitors cannot build on the new products a proprietary company has appropriated, the license change doesn't apply retrospectively. Newcomers can still use the initial code to develop software that challenges the company. A famous example is the Contrastive Language–Image Pre-training model (CLIP), a permissively licensed product that

learns visual concepts from natural language.[2] If CLIP paved the way to proprietary versions of GPT-3 and 4, it is also a core building block of Stable Diffusion, a product central to the operation of Stability AI, an open competitor to OpenAI's Dall-e, to which we now turn.

The Case of Stability AI and Stable Diffusion

For any new entrant in the market, the first challenge is to raise enough money to compete at scale. Funded by hedge fund manager Emad Mostaque, Stability AI is a company that owns the Dream Studio[3] and ClipDrop[4] platforms, where users can generate images with open-source models at different pricing schemes. To access large scale computing power, Mostaque raised 100 million dollars in venture capital (Wiggers 2022). His experience in the financial sector helped convince donors and secure the financial base. The investment was sufficient to give a chance to Stability to enter the market, but not large enough for Mostaque to secure a computational grid that would compare to tech giants. Even with comfortable seed money, Stability had to build an assemblage whose main trait is to re-balance the weight of the compute against other elements such as expertise and training data.

Stability AI developed an extensive network of research collaborators across the globe. In particular, the company tapped into the German AI research community. The Stable Diffusion algorithm created by Robin Rombach and colleagues in Munich had many appealing features among which was the ability to generate images faster by performing its calculus with compressed representations rather than pixels, a feature that drastically reduced computational requirements (Rombach et al. 2021). In contrast to OpenAI's secretive approach to knowledge, Stability AI provided an open environment to experiment publicly. The dynamics instilled by the project are well captured by Patrick Esser, a lead researcher on diffusion algorithms, who defined his ideal contributor as someone who would 'not overanalyse too much' and 'just experiment' (Jennings 2022). The project's politics of openness was motivated by the realisation that its ambitions exceeded the narrow goal of crafting a good product:

2 See https://openai.com/index/clip/
3 See https://beta.dreamstudio.ai/generate
4 See https://clipdrop.co/

> It's not that we're running out of ideas, we're mostly running out of time to follow up on them all. By open sourcing our models, there's so many more people available to explore the space of possibilities. (Jennings 2022)

As Google developer, Jason Baldridge, remarks, the release of Stable Diffusion's models under an open-source license brought about a change in the discourses and practices of AI image generation (Baldridge, Malevé, and Sluis 2025). The open-endedness of the project and its research ethos propelled an impressive series of innovations as a wide range of actors, from engineers to amateurs, began to tinker with a technology that was approachable and better suited to their scale. The flurry of diffusion-based models available on platforms such as Hugging Face[5] and CivitAI[6] testifies to the success of Stability AI's strategy. And the popular appeal of images produced by Stable Diffusion is reflected in the numbers as the algorithm is credited for eighty percent of the synthetic images generated in 2024 (Valyaeva 2023b).

Stability AI's attempt to minimise its hardware dependency informed its approach to curation. As Mostaque put it, one should not look for 'more parameters but better data' (Weights and Biases 2022). He commissioned the non-profit LAION to create the LAION-Aesthetics dataset, a collection of six hundred million image-text pairs. LAION-Aesthetics presents itself in the form a vast table in which each row contains the URL of an image, a description and a series of metrics including an aesthetic score. The combined factors of scale and the aesthetic filtering of the data helped Stability AI's team to train its model to translate the visual indications contained in prompts in a convincing manner. The importance of LAION's curatorial approach was further validated by Midjourney, a platform made famous for the diversity of styles it helps to emulate, when it chose LAION to train its model (Payne and Ramanathan 2025).

Stability AI invests in an ecosystem and helps make its disparate parts aware of each other and operationally connected. But this work of composition is risky and difficult to maintain. The first impediment is economical. Even if Stability AI has reduced its hardware dependencies,

5 A list of the 83,033 diffusion-based models offered by the platform is available here: https://huggingface.co/models?library=diffusers&sort=trending

6 Stable Diffusion-based models are available on this page: https://civitai.com/models

the budget spent on GPUs remains considerable. The balance between sharing resources with various communities and ensuring return on investment is impossible to strike convincingly in the long term. Experiencing heavy pressure from its financial backers, Stability AI struggled to deliver a product that it could monetise (Bastian 2024). Mostaque ultimately resigned after four years of leadership (Kokalitcheva 2024). The immediate lesson of Mostaque's resignation is that openness as conceived by Stability AI cannot exceed the limits set by investors. If Stability's assemblage recodes the AI platform's diagram, it can only do it partially as it remains firmly constrained by its funding mechanism. And the variation it proposes remains limited by the orientation of the diagram towards the material assets.

Stability's position is difficult for another reason. As its openness is its appeal, Stability's release of models and datasets has been less controlled and censored than those of other vendors. It has shown a liberal attitude regarding the appropriation of images. The LAION dataset it commissioned acquired billions of images without seeking permissions. And the circulation of models and codes helped all kinds of 'infringing' use to prosper. Models based on Stability's versions can Disneify prompts or generate images in the style of heroic fantasy artist Greg Rutkowski who complained that he had was being copied even more than Picasso (Hutchinson and John 2023). Whereas many proprietary platforms are also built on scraped data, Stability AI's policy of transparency made its datasets available for inspection through artists-run search engines such as haveibeentrained.com (Heikkilä 2024) that exposed the magnitude of Stability's use of online images. In that, its policy of openness opened its flank to legal attacks.

Image Values and their Discontents

To understand the reason of such attacks, it is worth considering the process through which models learn to create images. Algorithmic models used in current applications are said to 'learn' to make sense of images through the observation of the statistical regularities in a collection of visual samples. As these scraped images are obtained without permission from their creators, accusations of unfair competition and plagiarism proliferate. Artists and photographers are engaging in

boycotts and moving to the courts (Plunkett 2022; *Andersen et al v. Stability AI Ltd. Et al.* 2023). It is not clear at the moment if judges will decide in their favour as they will have to arbitrate between copyrights and many forms of exceptions (Samuelson 2024a). For instance, the defendants argue that the collection of data for the purpose of data-mining benefits from a specific exemption in EU (Moody 2024) and fair use in the US (Samuelson 2024b). In any case, the merit of these complaints is to lay bare the assumption shared by many closed and open AI platforms that, as Microsoft AI's CEO Mustafa Suleyman declared, content on the web is fair use per 'social contract' (Claburn 2024). Suleyman opposes the privileges accorded to authors by copyright to an exceptional economy where large-scale appropriation is an open game. This comment ultimately reveals how the radical de-valuation of 'content' is the necessary consequence of an industry revolving around the scarcity of hardware. Ultimately, Stability AI, like other platforms, bets on legal gaming to resist the artists' challenge. This shows that open platforms such as Stability AI do not stand in radical opposition to closed ones such as OpenAI. They add variations to a common relational diagram that gravitates around hardware dominance, but they don't radically break away from it.

If Stability AI is ultimately caught in its contradictions, the process of recoding the diagram of force of generative AI doesn't end with it. The variations on genAI's core set of relations can take different forms and intensities. To substantiate this claim, I am turning to AI Horde, a project originated in the Stable Diffusion ecosystem that further explores the consequences of re-orienting the forces circulating in the infrastructural assemblage.

Variation upon Variation, the AI Horde

AI Horde is a project that aims to create decentralised infrastructure for AI image generation. Initiated by a group of hackers in 2022, the project revolves around the figure of Konstantine Thoukydides, who operates under the pseudonym DivisionByZero. Thoukydides is a self-proclaimed anarchist who relentlessly advocates, theorises, and engages with the community of users and developers (DB0, n.d.). The Horde that extends to a loose network of collaborators is guided by the value

of mutual aid (DB0 2022b). As other image generators, AI Horde can be used as an interface to create images using prompts. However, the underlying mechanism is subtly altered. When a prompt is submitted, the process of generation is not handled by a central unit, but sent to a queue of requests where it is distributed to different machines that compute the requested images. The members of the community who have installed a dedicated piece of software called 'worker' (Haidra-Org n.d.), are performing the calculation and sending the results back. These members lend part of their computational power to the project when they are online. Their machine forms part of the larger AI Horde assemblage. Like the early SETI online project, AI Horde implements a distributed protocol that contrasts dramatically with the centralised architectures of tech giants where one entity, a given company, controls the process from beginning to end. With an average of 33 workers, AI Horde shares both code and infrastructure, and claims to have generated 118.4 million images since its inception (Stable Horde n.d.).

The distributed character of AI Horde's physical architecture reflects its politics. In contrast to dominant platforms that concentrate the decision power, AI Horde's architecture distributes governance decisions among the connected nodes. When a member adds their machine to the Horde's network, they select various parameters such as the models they want to run or whether the generated images can display NSFW content. Therefore, when a user types a prompt which contains explicit content or that must be processed by a given model, the request is routed to the nodes whose owners have agreed to these conditions and configured their machines accordingly. The architecture embeds a series of rules resembling a social contract that sets the conditions for sharing and the extent to which each participant decides what can be done with their hardware.

As I have shown, the funding mechanism of open infrastructures imposes limits to their development. As the material base is mutually shared by the contributors, the Horde, as a whole, considerably reduces its costs. In this manner, it operates with minimal funding such as an occasional grant. Its economical structure is further extended by an internal currency. The Horde uses a system of incentives that takes the form of Kudos (DB0 2022a) rewarding those who dedicate computer time to the project by giving them priority in the queue and the means to

generate their own images faster. Importantly, Kudos are also conceived as a mechanism against appropriation. If someone builds a commercial interface on top of AI Horde, the commercial app will not be able to siphon all resources for its purpose. The more it will use the Horde without giving back, the slower the network will respond to its queries. Unless the commercial actor gives computer time to the Horde, thereby feeding back into the project.

The Production of Aesthetic Scores

AI Horde largely makes use of the range of products generated by the Stable Diffusion ecosystem such as models and code. In return, its mode of production has implications for the larger open generative AI ecosystem. As the Horde has become a site of intense production and a meeting point for advanced users of the technology, their expertise gains value. For example, this leads to a partnership with LAION to produce better algorithmic aesthetic predictors (Thoukydidis and hlky 2023). The quality of a predictor is key to image generators as their value lies in their ability to provide users with environments to generate images that correspond to their taste. Producing good aesthetic predictors is a complicated task. In general, predictors are trained on large collections of images where microworkers rank them according to a set of aesthetic criteria. Even if the click workers are badly compensated, the annotation of large data collection remains costly. And the annotators often struggle with the aesthetic criteria they have to apply. Therefore, communities of users who are engaged in the production of images are highly valued by engineers both for their expertise and their interest in getting predictors that reflect their taste. AI Horde's partnership with LAION can be understood as a convergence of interests. Horde users evaluate images produced by Stable Diffusion models and rank them in order of preference. LAION is then responsible for turning these human judgements into data to feed aesthetic predictors. To encourage participation, AI Horde distributes Kudos to those providing such ratings. In accordance, users who rate images have priority access to the Horde's queue. And Stability occasionally donates access to its GPUs to the Horde in exchange.

As becomes apparent, AI Horde rebalances the assemblage's diagram by opening up the compute to myriads of contributors. It decentralises it and in doing that, it decentralises its governance to a significant extent. It doesn't achieve this goal only by changing the distribution of the compute. It also adopts a different relation to economy. It engages in the production of currencies that regulate its relations internally and externally. With kudos it encourages the sharing of hardware and prevents external abuse of its capabilities. By trading the aesthetic expertise of its community, it exchanges visual knowledge for access to GPU and the production of better predictors. AI Horde's economy is designed to operate at a scale which grows organically without the pressure of financial backers. It is nevertheless dependent on the production of software such as Stable Diffusion models that require heavy financial investments. Its intensive use of open-source products and code created in Stable Diffusion's orbit and its contribution to it in the form of aesthetic annotations testify to the solidarity and mutual dependency between open infrastructures of different sizes. As Stability AI, the case of AI Horde shows the modalities in which a common diagram centred on hardware dominance is challenged: through increasing variations rather than radical break. And, as all the products that circulate between Stability AI and AI Horde are attached to a license that allows and encourages sharing, they demonstrate the crucial role played by legal coding.

Conclusions

In these pages, I have followed the work of composition involved in genAI infrastructures. Instead of considering the ownership of technical assets such as computing power for itself, I focused on the mode of relations they condition and the strategies they elicit. Guided by assemblage theory, my analysis concerned itself with the transitive character of infrastructure: its ability to move between the material and the possible. I sought to discern a space of possibility within material constraints. To this end, I have identified a diagram that encapsulates both the limits and the potential for variations tested by the actors. In that perspective, I have shown how open infrastructures of AI image

generation develop strategies to rebalance their dependencies on the compute. Stability AI did so by expanding the idea expressed by Mostaque, for whom to have better models, one might not need more parameters but better data. Here, curated and annotated images play an essential role. In contrast, Stable Horde focuses on the hardware topology itself by distributing the compute over semi-autonomous nodes. Both strategies aim to recode the same infrastructural diagram where the forces in presence are not oriented towards the tangible assets of the infrastructure and its large-scale investments in chips, GPU, and electricity. The political relevance of these projects lies in the fact that this recoding goes beyond a mere practical rearrangement of the material base. It touches upon the positionality engrained in hardware dominance as it is leveraged by hegemonic platforms. What is contested is the logic allowing large companies to work upstream and dictate the terms under which others work downstream. As knowledge production is negotiated along this positionality, the strategies devised by open infrastructures also include a different relation to the stimulation and circulation of expertise. Stability AI invests in large scale public experimentation by funding and offering a test ground for researchers. More modestly, Stable Horde valorises the creative expertise of its members and collaborates to develop an aesthetic predictor, a key component of the genAI toolchain.

In doing so, both initiatives operate crucial variations on a set of constrained relations imposed by the hardware requirements. While divesting from the gravitational pull of the compute, they open up their mode of governance to a larger set of actors and a more participatory process where the communities involved gain traction. For Stability AI, this ultimately leads to contradictions that cannot be resolved, as its investors and users have diverging agendas. For AI Horde, this is cemented in the networked architecture of the project where each node has control over the services their machine offers to others.

If these projects exhibit real differences with closed infrastructures such as OpenAI, their differences must be nevertheless understood as part of a process of continuous variation. They explore a same space of possibilities under constraint. They are alternatives inside a world invested in property, not outside of it. Therefore, a

form of continuity underlies the dichotomy between open and closed infrastructures. This is expressed through a legal game that allows open and closed systems to appropriate labour. In fact, the mutability of the structures of intellectual ownership is the principle that guides the strategies with which hegemonic platforms capture an economy of collaboration. But as a corollary, this legal agility also allows for other projects to take off. For example, Stability builds on top of software developed by OpenAI before it became proprietary. This mutability conditions how various attempts to build generative AI platforms relate and depart from each other. Each one builds a divergent assemblage rather than a radically different one. From OpenAI to Stability to Stable Horde, we discern different waves of variation on a same mode of production where each project rewrites the assemblage, re-orients the direction of its forces, re-weighs its components and reaches out to recruit more actors.

Further, the continuity between open and closed infrastructures implies that open infrastructures also engage in practices of appropriation. Like their counterparts, their economy can only function if the value of the billions of images used in training sets is negated and treated as raw material to produce models. And like closed infrastructures, they bet on the legal gameability of the copyright framework to be able to do so, with the clear difference that they openly release and circulate the models produced with appropriated materials. If open infrastructures are controversial as many pending court cases attest, it is not because of the extent to which they oppose closed infrastructures, but rather the degree to which they resemble them. However, at the time of concluding, I would like to insist that such difficulties should not detract from the merits of these initiatives. On the contrary, in the recent context of increased state investment in AI as seen in the US Stargate project (Boak and Miller 2025), the agenda of AI sovereignty in Europe (Madiega 2020), or the 'Made in China 2025' plan (Al Midfa 2025), the centralisation of platforms and their associated problems of dominance are likely to increase. As alternatives, open infrastructures are more necessary than ever. But as the stakes are higher, the need to understand their complexities, contradictions, limits and potential increases accordingly.

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V. INFRASTRUCTURING OPENNESS IN THE FUTURE

15. Infrastructuring Openness or Opening Infrastructures?

Annalisa Pelizza and Renée Ridgway

RR: Today I'm conversing with Prof. Annalisa Pelizza. Annalisa and I both work at Aarhus University in the Digital Design and Information Studies department. We, the editors of this volume, invited Annalisa to talk about her research on infrastructures through the lens of the *Politics of Open Infrastructures*. To begin, how would you frame the notion of open infrastructures?

AP: Thank you for this opportunity to have a dialogue about a key topic in the infrastructure studies community. I wondered about your question when I read the book call. To begin, I suggest that infrastructures are always to be considered in the 'ing' form. And that's what the scholarship of Barbara Czarniawska has stressed: her work foregrounded 'organizing' more than 'organizations' (2014). That's even more important for infrastructures—focusing on the dynamics of connecting or disconnecting rather than on stabilised objects. This being said, 'open infrastructures' made me wonder whether we're talking about 'infrastructuring openness' or 'opening infrastructures.' The first case might sound a bit deterministic, because what is 'openness' for someone might not be 'openness' for someone else. 'Opening infrastructures' is more interesting for me because it triggers questions about how do we know infrastructures and how do we methodologically study infrastructures. How do we as researchers open them up? But also, how can we follow power in infrastructures?

I also see a temporal dimension about 'opening infrastructures.' How long can we keep infrastructures open in order to study and transform

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them? How can we concomitantly make them more symmetrical, more just and fair? I feel that we need to study infrastructures in their everyday operational activities. How do we keep infrastructures open to study them not only during breakdowns or during their design stages, but also in their mundane operations? This is particularly important with data infrastructures that shape the minor details of our lives. Also, concerning a broader time frame, how do we keep infrastructures open to be acted upon with a long-term perspective? Some colleagues in information infrastructure studies call for longitudinal studies (Pollock and Williams 2008). But longitudinal studies are also very inconvenient because they don't fit to contemporary academia. Let's think of a PhD career that is three or four years long. How could a PhD conduct longitudinal studies? Does it mean that information infrastructures can only be kept open by tenured researchers? My idea of 'opening infrastructures' is linked to all these methodological issues, which are, in turn, deeply linked with the organisation of research.

RR: That's helpful because besides 'openness,' the book focuses on knowledge infrastructures and how they relate to not only the political but also questions of power. You said that an infrastructure in itself does not have power. Could you talk more about this relationship?

AP: I see at least four, maybe five, ways in which science and technology studies or infrastructure studies have addressed power and the political. Among these, I adopt a relational understanding of power. I don't think that power is a substance that somebody holds; it's not an object that circulates. Power is the result of how a relationship unfolds. An infrastructure doesn't 'have' power because infrastructuring is always about arranging relations, and such relations are dynamic. The outcome of an infrastructure can be multiple and contingent.

RR: Could you please share some of your research as an example?

AP: In 2021, I published an article in the *Journal of Information Technology* based on research in which I analyzed the process of making governmental information infrastructures interoperable in two different contexts. One was Italy, the other one was the Netherlands. The former was about making two administrative systems interoperable, and the latter about making the land registry ecosystem interoperable. Both

cases used open-source software. So you might expect that openness is inscribed already in open-source software. Openness is at least the goal of open source. And still, the way interoperability was achieved in the two cases had different outcomes. One case finished up by excluding the same civil servants who were commissioning the job, the other case to exclude potential suppliers and keeping the job in-house, within the government. So that's an example of how the outcome of an infrastructure can be multiple and contingent. Openness is not defined a priori exclusively by the fact that open-source software is used.

RR: That's really interesting, my chapter is actually about the value of openness in regard to FOSS, FLOSS, or open-source software. There I draw on Star (1999) and Star and Ruhleder's (1994) use of the term 'ecological' and that they're relational material constructs made by humans, never 'just a thing,' as it's about the network surrounding them and the actors involved. In your research in Italy and the Netherlands, humans were involved in the entire process. You discuss openness through the interoperability of infrastructures and how it reorders institutions, but in other research you call it a 'vector glance,' to refer to how interoperability also constructs people in different ways.

AP: What I like about 'infrastructuring' is that it is a set of practices that extend in time and space, or material practices that you don't know beforehand, but you can see how boundaries are a network of practices. It's very difficult for me to say that something is a network and that something surrounding the network is external to it. In a sense, artifacts and actors, humans or non-humans emerge in their being part of the practices and being part of the network. And it's going to shift accordingly. I don't distinguish 'the ecological' as a substance. I look at ecology as networks of parts, be them humans or non-humans interacting and not simply as standing as a backdrop. So in that sense, in my research an actor can be a human but also a bracelet (Pelizza 2020). I conducted research at migrant registration and identification centres at European borders, at the so-called 'Hotspots.' People rescued at sea are given bracelets by NGO operators, and they wear these technologies, very low-tech artifacts that sort them on board. These bracelets do things to people. Therefore, they have agency. And this agency can be the one intended by humans, but can also be, or turn out to be, some other

form of agency. For example, bracelets can articulate much broader relationships between, in this case, NGOs and the state apparatus. If positioned in a given space-time, bracelets can have agency, can force the state to act in a certain way—for example, by treating people before fingerprinting them. Otherwise, in other positions in the infrastructure, they can be meaningless and therefore not even be noticeable.

RR: 'Opening infrastructures' is both a methodological entry point and consists of multiple and contingent agents, right? Yet when is an infrastructure finished?

AP: A finished infrastructure for someone might be an impediment for others: again, this has to do with power. There is also an ontoepistemic dimension to that. I once wrote about this with Claudia Aradau in an introduction to a special issue in *Science, Technology and Human Values* (Pelizza and Aradau 2024), by developing the idea of contingency and obduracy that has obsessed me for quite some time. So 'when it's an infrastructure, obdurate or established, it is finished.' But we have always understood infrastructures as contingent, as always becoming, as always emerging in use and not only in design, haven't we? I don't think we can only stick to the postmodern understanding of contingency. We should also account for how things *become* obdurate, and this is what infrastructures are trying to do, in a way that it is not the very rigid distinction between structure and agency. When is an infrastructure finished? I don't think infrastructures can ever be finished, because they can always be reworked. But surely it can be in operation, which means that a trade-off between its continuous becoming and its enabling character has been reached. And there are costs to rework an infrastructure, to reopen it. These costs might be epistemic, might be financial, might be organisational, might be labour-related.

RR: Could you cite a case, or an example?

AP: I see this very clearly when I work on government information infrastructures. A lot of government information infrastructures are failed infrastructures. Not only are governmental agencies lagging behind the private sector and all those kinds of discussions, which in my work I have tried to historicise. Private infrastructures can also fail! The point is that when it comes to public spending, infrastructures cannot

be said to have failed. They have to be obdurate. They have to become stabilised. And that's part of the state as an 'effect,' as Mitchell (1991) called it. I would say that infrastructures are finished when they are said by some actors to be finished. Then it comes to the point of what is the power of enforcement of those actors.

RR: Could you apply this to your research on European borders?

AP: If a person who is on the move, someone who is usually called a 'migrant,' says that an infrastructure failed, this doesn't have the same effect of someone from the IT department in the Ministry of Interior saying that infrastructure has failed or, on the contrary, that the infrastructure is finished.

RR: Is this another way to phrase what you call 'active enunciation?'

AP: Exactly. I actually have a background in the theory of language, but when I was a PhD student I went into more material-related understandings. Yet I still hang on to this idea of an act of enunciation where enunciation is not just discursive—it can also be an act of design or of using an artifact. In that sense I connected to the lesson of Latour, whose work I approached as a student from a socio-semiotic perspective.

RR: Technology is society made durable?

AP: Yeah, exactly. It's basically a matter of how agency travels. Through acts of translation. And then it's not that any act of translation is equivalent. Definitely not. It's always a betrayal.

RR: Are there more tools that can help us understand how language is being captured as data at borders? There is an applicant and there is an interpreter.

AP: Applicants are identified several times, not just once. We called it 're-identification' (Van Rossem and Pelizza 2025). There are iterations of identifications. But each iteration uses a different materiality. And this is how infrastructures become obdurate or finished, going back to the idea of finishing an infrastructure. Imagine there is an officer, the interpreter and the applicants (see Pelizza 2021b). Their interaction is mediated by a computer, but it's also mediated by a piece of paper. And the applicants

give their name orally. Voice is already one form of materiality. Which is not the same as writing the name on the piece of paper nor is it the same as writing on a digital system interface.

Why isn't that the same as typing the name into a digital system, or a database? Well, because giving the name orally is in the here-and-now—what can be reproduced is only the sound. Then writing the name on a piece of paper adds a further element, which is transliterating, for example, an Arabic sound into writing. And this writing should usually be in Latin fonts, not in Arabic fonts. So, this is already a form of betrayal. What I also noticed is that a lot goes on around that piece of paper circulating among applicant, interpreter and officer. Only once there is a shared transliteration, the name is registered in the digital database. Why? Because the digital database travels across time and space. Not even the officer inputting the name knows who will read the name at some point throughout Europe. This is very different from having a negotiation among three persons at the same table in the same moment. These are three forms of materiality that involve different actors and they have different power outcomes, of course.

RR: What just came to mind is how the established notion of a boundary object changes—the written compared to the digital database. This is the problem with data privacy and data digital information as it can be used in one way and then it travels to all these different actors and we don't know where it's going to wind up. Even when it was written on paper in the archives it had a kind of static life, though various parties could access it, another distinction from being in the here-and-now of the world. Bringing this back to classical STS infrastructure studies, what came to mind in regard to 'opening infrastructures' is how the boundary object can travel yet it retains something that's recognizable even though it could be a database, a folder or a map. Mongili and Pellegrino's book relates to information infrastructures that are not something only made by information (2014). They are made of heterogeneous elements. This 'opening up' of infrastructures and these boundaries converge quite literally in regard to your research on borders.

AP: I agree. At the moment, what is interesting for me is which kind of boundaries do objects articulate? Where does the object operate the cut? Star discusses, together with Bowker (1999), that infrastructures are not

just a kind of object. The most important issue to me is that infrastructures define communities of practice and are defined by the communities of practice. Where are the boundaries? Where are the cuts drawn? For me, that's where the political lies. You enquired whether there is a kind of essential core that remains in the boundary object. I don't think that we need to adopt an essentialist understanding when we talk about boundary objects. We can always keep a relational understanding, even if we are looking for what stays, what remains obdurate.

RR: In a way, it goes back into contingency and obduracy that you mentioned before. Somewhere you mentioned the relationship to how, or where socio-materiality lies in rethinking the synergies between STS and information infrastructure studies in the age of datafication. Yet where do the boundaries lie? Even with STS? How does information infrastructure studies play into this? Because there's this engagement with the technical artifacts and then there's different trends going on and specific fields of studies in regard to these epistemological debates and theoretical insights.

With this line of reasoning, you define information infrastructures as not something that's only made by information. This would be illogical given that infrastructures are made of heterogeneous elements. Rather, information knowledge goes back to knowledge infrastructures and data, what they are expected to produce. At least, if you're looking at them at first sight. Is your argument that they produce more new legislation, new organisations, de facto new actors?

AP: Yes, that's basically the argument I am trying to develop in the long-term. The production of information, data and knowledge is the normative goal that justifies the development of these infrastructures. But that doesn't mean that infrastructures are made only of information, data, etcetera. Infrastructures are also made of laws, or organisational practices and absolutely, people. Information, data and knowledge are what is expected to be the outcomes. But my idea is rather that also new assemblages of actors as organisations are made by producing information and by infrastructuring for information production. New de facto articulations of actors.

RR: Would the governance project be a concrete example?

AP: The *Processing Citizenship* project on the digital identification of people on the move at the European borders provided some examples.[1] Migration management in Europe is based on the so called 'Dublin system,' a legal framework that established that if someone has lodged an asylum application in a Member State, they cannot lodge a second application in another Member State. *Eurodac* and the multi-level data infrastructure for migration management implement this legal provision. Dublin units have been established in the ministries of interior of EU Member States as organisational units dealing with this sociotechnical process. They didn't exist before the introduction of the security infrastructure for migration management. These units are not formally new, they are made of people who were already working there, but they are endowed with new functions, and they are connected across borders. Sometimes they have to hire new people. In any case, the important aspect is the fact that Dublin units coordinate across Europe in a way that they create a community of practice. If you don't follow the infrastructure, you won't be able to see it. You just see the Ministry of Interior.

Now I am working on the European digital identity wallet in the 'Governance by Infrastructure' project. Also at the supranational level we see new actors emerging that didn't exist before. For example, the agencies releasing an 'electronic attestation of attributes.' They might be new or old organisational bodies but the point is that they have new functions and they need to be created inside organisations to deal with the issues raised by the European electronic identity. Therefore, these key actors in the infrastructure for European electronic identity are somehow new. It's not important whether these people were already working there or they were hired from scratch. The point is that these are aggregations that have new functions and deal with new problems, with new challenges that didn't exist before.

RR: If governance is conceived as a de facto outcome of infrastructure, is this result based on 'opening infrastructures'? Because you're saying we have a more open perspective about what the potentials are. The digitalisation for institutional geography of responsibilities is a more

1 An archive of the project website is available at https://www.annalisapelizza.eu/wordpress/processingcitizenship/

ethical response or the possibilities emerging within citizen science and with the way that 'opening infrastructures' can evolve. Is that also part of your project about governance by infrastructures?

AP: I have wondered whether digital infrastructures have become a trap. They were developed decades ago pursuing transparency, exchange and in some cases efficiency. Since then, they have been appropriated and reused in ways that enhance control, but also the taking over of the means of data production by actors who have a disproportionate power of enforcement (Pelizza 2018). With this, I'm referring indeed to the fact that a lot of infrastructures have been turned around for different purposes than for what they were originally designed. There is 'scope creep' going on in many fields, especially governmental infrastructures. Look at the Bureau of Fiscal Service, which is a branch of the US Treasury Department that is responsible for almost ninety percent of federal payments, created with the goal of paying employees and contractors, etc. In February 2025 the staff from DOGE in the US tried to get access to their very sensitive information systems, and apparently, they got access to it and turned user information over to this or that infrastructure for use in different purposes. The point is that digital infrastructures are always open for contingency and different uses than they were designed for.

RR: There are people really trying to come up with other alternatives to Big Tech. I think the Euro Stack is the next thing on the agenda for Europe as well as the digital wallet project. People are also promoting "open source," but what type of open source? It is not just a business model or co-opting the commons but media hype. How can we as Europe proffer a response as a kind of pushback? Maybe through these types of projects. Or by reconfiguring ethical considerations and obligations or handling personal biometric health and environmental health data from the perspective of STS, critical data studies, and critical infrastructure studies as well.

AP: I agree with the idea that somehow we can't just circulate data on Silicon Valley platforms. You made the example of citizen science, which is a way to produce knowledge that produces also communities of practice that are very different from actors that are enacted by data circulated on Facebook or Instagram.

RR: Because what I've learned from talking with you is that 'opening infrastructures' is about producing communities and not just producing data, which ties back to how relationality, or an ecology is not just about things. It's about all these different actors and actants coming together. In a way, if I may say, you're doing an 'infrastructural inversion,' but then you're doing it by saying, I think it's about 'opening infrastructures,' not 'infrastructuring openness.'

AP: Yes, I don't want to bring in a deterministic perspective. Instead, an interesting direction of research is the difference between infrastructuring and research on infrastructures and research on social media. There's a lot of research going on at the moment on platformisation. Within the community on information infrastructures, we are trying to keep it distinct, as infrastructural boundaries are not clear-cut. We know who owns platforms, we know who develops platforms. Infrastructures is a concept that was born in the nineties. And in that sense, it keeps an indeterminate perspective. Infrastructures are not owned by only one company. So infrastructures are also integrations that continue to become. And somehow they are much broader than platforms.

RR: On behalf of Astrid and Katja, we thank you for this conversation.

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16. (Trans)action Cycles: New Resource Architectures for a Digital Commons

Katharina Meyer

> Many core technologies increasingly resemble [...] air, water and a habitable earth—resources that are expected to be accessible to, and managed in the interest of, all members of society. [...] Shifting our view to see technology infrastructure as a (digital) commons could begin to create more flexible, responsive and regenerative systems to build and deploy technology.
> —Divya Siddarth (2021)

1. Introduction

Open digital infrastructure (ODI) must be recognised and sustained as an essential public good. Unless we reimagine how such infrastructures are resourced, the digital commons will remain fragile, extractive, and vulnerable to capture. As Director of the Digital Infrastructure Insights Fund (D//F)—a strategic research funder active since 2018—I have worked with and commissioned work consistently indicating that ODI such as protocols,[1] code libraries,[2] repositories,[3]

1 E.g. Open Archives Initiative Protocol for Metadata Harvesting (OAI-PMH), see Open Archives Initiative (2023).

2 E.g. Scikit-learn, a widely used open-source machine learning library, see Pedregosa et al. (2024).

3 E.g. Software Heritage, the world's largest public archive of source code, see Di Cosmo et al. (2023).

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and technical standards[4] form the backbone of our digital society and are indispensable to the functioning of democracies, organisation, knowledge-creation, information distribution and innovation.

'Open digital infrastructure' here designates the permissively licensed, multi-purpose system components that support commerce, science, communication, and administration (Bloom 2023; European Commission 2023a). These infrastructures form part of the digital commons: shared digital resources that, if they are to serve the public, must be governed to resist enclosure and free-rider exploitation (Berlinguer 2021; Hess and Ostrom 2007). To treat ODI as civic infrastructure means centering the public interest, understood not as private profit but as value negotiated among diverse stakeholders, rather than determined by technical design or market dominance alone (Mazzucato 2023). At the same time, I argue that resourcing is infrastructuring: the flows of money, labour, and legitimacy that do not merely support infrastructures but actively constitute them; funding itself is infrastructural work (Meyer 2020; Yin et al. 2022). To capture these dynamics, I introduce the notion of (*trans-*)*action cycles*: recurring loops of material and immaterial resource transactions and governance actions across funders, (technical) communities, and intermediaries that shape and sustain infrastructures. These cycles are deliberated and fragile, but they can also be designed to be resilient and regenerative (Berlinguer 2021).

While the FOSS community is diverse, decentralised, and geographically dispersed, core infrastructure projects are typically maintained collaboratively by experts, governed in tripartite constellations (Berlinguer 2021)—and while they are relied upon globally yet remain structurally fragile (Eghbal 2016; Plantin et al. 2016). D//F was created to highlight their systemic importance and to mobilise institutional capacity where other actors had fallen short. Initiated by a coalition of philanthropic funders, chiefly the Ford and Sloan Foundations, it emerged from the recognition that neither markets nor states were providing sufficient, long-term support for these critical digital infrastructures.

4 E.g. HTTP/1.1 (Hypertext Transfer Protocol), an open IETF standard underpinning the World Wide Web, see Fielding et al. (1999).

The Ford Foundation's 'Roads and Bridges' report (Eghbal 2016) had already documented the invisible labour and thinly stretched resources underpinning core open-source software—and the persistent free-rider problem—to wide acclaim at this point.

D//F was founded as a field-builder: not only to disburse grants, but also to curate and update knowledge, shape agendas, and bring open infrastructures into policy debates. Its mandate is to strengthen the legitimacy of ODI as civic infrastructure by investigating how these systems are built, maintained, governed, and resourced. To date, four funding cohorts have supported work across six thematic areas: sustainability and funding models; governance and institutional design; security and resilience; equity and participation; political economy and public value; and the epistemic and socio-technical dynamics of ODI.

D//F operates as a boundary institution, making the often-invisible foundations of open digital infrastructures legible. By convening across technical, philanthropic, and policy domains, it frames ODI as civic assets requiring long-term stewardship in the public interest. In doing so, D//F demonstrates how intermediaries can surface overlooked dynamics, test new resource arrangements, and open pathways for reform. Projects have examined, among others, the multi-billion-dollar browser–search revenue market (Browser Funding),[5] community health and sustainability frameworks for open source (CHAOSS, FOREST, POSI),[6] and the impact of tech-sector layoffs on free and open-source software (FOSS) communities (Infrastructure in Recession).[7]

In what follows, I trace the fragilities of open digital infrastructures—rooted in market failures, underproduction, and contested boundaries of openness—before comparing emerging funding models across philanthropic, state, and private initiatives. I then reflect on D//F's role as a convener across these domains and close with an outlook on institutional prototypes developed at the SOAM Residency 2025, from maintenance trusts to digital infrastructure bonds, designed to balance stability, equity, and sovereignty.

5 See https://infrastructureinsights.fund/projects/browser-funding/
6 See https://infrastructureinsights.fund/projects/oss-research-software/
7 See https://infrastructureinsights.fund/projects/infrastructure-in-recession/

2. The Problem Space: Fragility, Market Failures, and Boundaries of Openness

The fragility of open digital infrastructures is no accident; it is the direct outcome of market/coordination failures and institutional neglect. Despite their systemic importance, ODI remain subject to an exploitative dynamic: states rely on them for critical administrative functions, corporations build billion-dollar businesses and R&D on their foundation, and citizens depend on them daily in communication and economic participation—yet fairness, accountability, and responsibility between stakeholders remain diffuse (Plantin et al. 2016).

The Linux Foundation's *State of Commercial Open Source Report 2025,* for instance, shows that although a majority of European organisations adopt open-source software, only forty-two percent contribute substantively, and nearly a quarter (twenty-three percent) admit to making no contribution at all (Linux Foundation Europe 2025). This is not merely an efficiency gap, but a structural injustice—a free-rider problem in which nearly everyone benefits while few contribute proportionately. The gap between the value generated by open systems and the value captured by markets continues to widen. Dries Buytaert (2025) cites studies estimating that replacing widely used open-source software with proprietary alternatives would cost 8.8 trillion dollars globally. Yet ninety-six percent of this vast web of dependencies—software, social ties, and skills—rests on just five percent of contributors, many of them unpaid. Core coordination work such as bug fixing and documentation remains systematically undervalued in prevailing financing models (Eghbal 2016).

Conventional funding and resource allocation logics treat needs as measurable by headcount or feature output, overlooking the less visible labour of patch review, issue triage, and security maintenance. While newer AI-assisted coding tools now automate parts of testing, bug detection, and refactoring, they also generate higher volumes of machine-authored code that still requires human oversight, especially in open-source projects. Maintainers continue to report additional coordination and review burdens, even where teams experience productivity gains.

(Stenberg 2025; Becker et al. 2025). Resource models must therefore account for coordination work, not only visible code output. If neglected, these expanding costs will continue to be externalised onto already under-resourced communities.

Crises generally serve as an amplifier: the 2014 Heartbleed bug in OpenSSL—a critical flaw in widely used cryptographic software—revealed how much global security depended on just a handful of volunteers. The 2021 Log4Shell vulnerability—a remote-execution bug in a ubiquitous logging library—showed how quickly a neglected dependency could spiral into a global emergency. Maintainer withdrawals from essential libraries—projects abandoned by their core developers—exposed the limits of unpaid labour and the burnout that precarity breeds (Wikipedia 2023a; 2023b; 2023c). Even Wikipedia, one of the most mature open projects, recently reported infrastructure stress and skyrocketing server costs from AI crawlers siphoning data for model training (Noroozian 2025; Maxwell 2025). This led to Wikimedia Enterprise forming API partnerships with Google[8] and AWS.

Like education or healthcare, ODI are both public goods (non-rivalrous, non-excludable) and merit goods (societally valuable but under-provided by markets). Without institutional support, we remain trapped in cycles of neglect punctuated by crisis (European Commission 2022). The boundaries of openness are not fixed, but constantly contested. Licensing regimes illustrate the dilemma: their governance must balance sustainability against capture, without undermining accessibility. Recent experiments—from Creative Commons' Signals framework for AI-age reuse (Creative Commons 2025) to dual-licensing strategies by Redis and Elasticsearch that were later reversed under community pressure (Heise 2025; Clark 2025)—show that none offer an easy resolution. Instead, they underline the core argument: openness is not binary but political, and its boundaries must be actively governed and re-negotiated if infrastructures are to remain resilient, equitable, and in the public interest.

8 See https://wikimediafoundation.org/news/2022/06/21/wikimedia-enterprise-announces-google-and-internet-archive-first-customers/

3. Comparative Funding Models: Emerging Institutional Diversity

Across the globe, funders and governments have launched experiments to secure open digital infrastructure, each reflecting a different political economy of responsibility—some leaning on philanthropy, others on state intervention, private capital, or collective self-organisation. Cross-border state-backed programmes reveal both promise and fragility: the US-based Open Technology Fund (OTF), once a longtime supporter of privacy-preserving communication tools like Tor and Signal, has faced repeated defunding threats—underscoring the vulnerability of infrastructures dependent on discretionary public budgets (OTF 2022). European micro-grant initiatives such as NLnet and the Next Generation Internet (NGI) programme lower barriers for early-stage developers, yet rarely sustain projects beyond prototypes and must renegotiate resources with each EU budget cycle (European Commission 2023a). Neither model has achieved the permanence of utilities or public broadcasting.[9] National initiatives are also emerging to institutionalise stewardship. Germany's Sovereign Tech Fund (STF), created in the wake of the Log4Shell vulnerability, signals a recognition of digital infrastructure as public good. Its mandate is to fund critical open-source components in the public interest. However, continuity depends on political will and stable budgetary allocations, raising questions about whether such programs can achieve long-term institutionalisation (Sovereign Tech Fund 2024). A different extension of state-led stewardship can be observed in development cooperation. Germany's Fair Forward program, for example, directs resources toward open tools, datasets, and skills in the Global South, positioning open digital infrastructures as instruments of sovereignty and inclusion.

In Global Majority contexts, where infrastructural asymmetries are particularly pronounced, such investments position digital openness as part of broader development strategies (SSIR 2023). Yet this potential is increasingly constrained: recent reductions in public development cooperation budgets have significantly curtailed the scope for sustained support.

9 See European Commission cuts funding support for Free Software projects.

In the global research domain, Invest in Open Infrastructure (IOI) complements these models by acting as a meta-funder and convener: Through its State of Open Infrastructure mapping, IOI generates rare field-wide visibility for research software, aligns shared priorities, and coordinates pooled funding experiments (IOI 2023; 2024).

Other models build on collective solidarity within specific sectors such as higher education: the Global Sustainability Coalition for Open Science Services (SCOSS) pools contributions from libraries and consortia to stabilise scholarly infrastructures such as arXiv and the Directory of Open Access Journals (DOAJ). By coordinating resources across multiple funding cycles, SCOSS illustrates how consortial approaches can sustain research commons (SCOSS 2023). Registry-derived funding offers another pathway. Unlike philanthropy or sponsorship, these revenues flow from quasi-public assets—domain registries—and are relatively insulated from political volatility. NIC.br in Brazil and CIRA in Canada, for instance, redirect registry income toward research, training, and resilience; ICANN is redistributing roughly US$217 million in auction proceeds for Internet stability (SIDN 2024). Such designs resemble utilities or cultural endowments, channelling infrastructural revenues toward collective benefit.

Finally, corporate and community sponsorship platforms such as GitHub Sponsors or OpenSourceCollective facilitate direct financial support for maintainers. While these mechanisms highlight the potential of distributed, bottom-up contributions, their effects remain uneven. Funds tend to flow toward high-visibility projects or charismatic individuals, while critical but 'boring' dependencies—often the backbone of digital systems—remain neglected. Such asymmetries underscore both the promise and the limits of voluntary, community-driven models for sustaining infrastructural resilience. Same goes for experiments in retroactive funding.[10]

Taken together, these initiatives show the growing recognition of ODI as a public asset. But they also demonstrate the fragmentation of the field: philanthropic and micro-grant schemes are short-term, private capital inflows lack fair-share principles, state-backed programs remain politically contingent, and registry funds depend on market dynamics.

10 See https://gitcoin.co/research/retroactive-funding-most-scalable-pattern

None have yet achieved permanence on the scale of utilities—the basic public service systems such as water, electricity, or telecommunications that are stabilised through statutory guarantees, tariffs, and universal service obligations—or public broadcasting institutions, which combine predictable revenues with civic mandates.

The urgent task, then, is to design resource architectures for ODI that embed the same qualities of durability, equity, and adaptability, rather than patching the gaps left by provisional fixes or precarious experiments.

4. D//F as a Boundary Institution: Design Tensions and the Politics of Resourcing

D//F is best understood as a boundary institution: influential less through budget scale than through its ability to convene across domains and reframe sustainability. Boundary institutions (Guston 2001; Star and Griesemer 1989) occupy liminal spaces between science, policy, and civil society. They translate across worlds with different reasoning, creating coordination without demanding full consensus. From this in-between position, D//F has acted as a broker: between technical communities and implementers, between philanthropic logics and rationales of other sustainer stakeholders, and between policy and innovation imaginaries. Through events and commissioned research, it has rendered ODI legible to audiences far beyond software development, pulling maintenance work into conversations on innovation, prosperity, and democracy.

While this position creates leverage as agendas can crystallise across sectors, it also carries fragility. D//F's legitimacy still rests on temporary philanthropic alignment in form of a funding pool rather than statutory anchoring. Institutions like D//F are crucial in reimagining governance, yet their own long-term impact depends on more durable forms of resourcing, such as endowments or public mandates.

The work of resourcing open digital infrastructure brings into focus a set of recurring design tensions. These are not abstract dilemmas; they appear in the daily negotiations between funders, maintainers, and policy makers. Four in particular stand out:

- Temporalities: Infrastructures endure for decades, yet most grants run 12–36 months. This mismatch breeds instability and chronic precarity; Heartbleed revealed how critical cryptography went under-maintained for lack of long-term support mechanisms.
- Legitimacy: No shared standards exist for what counts as critical public-interest infrastructure. Mundane dependencies are routinely overlooked until crises. Log4Shell exposed how invisible components can become global security risks yet rarely attract recognition beforehand. Designation as 'critical' is political and relational rather than universal.
- Distribution: Resources cluster around visible and historically 'central' projects, while dependencies and contester initiatives are systematically underfunded. Flagship projects attract sponsorship, while translation, accessibility, and documentation remain neglected. This also reproduces epistemic inequalities, as existing Global South infrastructures remain invisible to Majority funders.
- Responsibility: Major beneficiaries—corporations and governments—often free-ride which externalises costs onto communities. States depend on FOSS for public services yet often intervene only after crises and within restrictions. One such limitation is the requirement that states refrain from distorting markets through intervention, except within strict regulatory frameworks. Corporations only contribute on voluntary basis, dependent on resource availability. Responsibility is widely acknowledged in rhetoric but rarely institutionalised in practice.

These tensions echo other public-goods domains but are intensified by the speed and scale of digital change. It is precisely through boundary work that these tensions become visible and can be held together, though always in a provisional and contested way.

Sustainable design and thus resourcing cannot be reduced to technical fixes or piecemeal grants. It requires confronting these tensions as political choices and designing funding architectures that are financially robust, reciprocal, and adaptive.

5. Outlook and Conclusion: Towards New Resource Architectures

As demonstrated, resourcing is not ancillary to infrastructure; it is infrastructural work in its own right. If left to market logics and short-term contracts, open digital infrastructures will remain precarious, underfunded, and prone to capture. If, however, they are treated as civic infrastructures, they can be stabilised for the public good. The question is not whether they need to be resourced, but how—and in whose interest.

A resilient architecture will combine instruments rather than search for a single solution. At the SOAM Residency 2025, *Re:Fund Our Digital Future*, organised with TUM Think Tank's Transformation Finance Lab and Digital Future Architects, several institutional prototypes were screened that point beyond piecemeal fixes:

- Commons Maintenance Trusts: Permanent, cross-sector trusts pooling contributions from governments, industry (and civil society), to endow maintenance of critical components; governed by multi-stakeholder boards and insulated from short political cycles (Global Solutions Initiative 2021).
- Resilience-by-Design Funding: Embed ODI upkeep within mainstream R&D and public procurement (e.g., fixed percentage for upstream dependencies), normalising stewardship as part of innovation.
- Legally mandated redistribution: Procurement rules and regulation could require vendors to reinvest in dependencies; the EU's Cyber Resilience Act signals movement toward supply-chain accountability.
- Extended Producer Responsibility (EPR): Adapted from environmental law, EPR would hold major platforms responsible for sustaining the open components they rely on.
- Public Value Audits/'Open ESG': Require transparent reporting of contributions (funding, staff time, participation in standards) to create accountability.

- Digital Infrastructure Bonds: Mobilise long-term capital (modelled on green bonds) for security overhauls, major maintenance, or endowments; repaid through general revenue or targeted levies.

Analogies to other domains are instructive. Climate finance mobilises long-term, cross-sector resources for planetary maintenance. Cultural commons (e.g. museums) rely on mixed funding architectures blending state, philanthropy, and earned income. Public broadcasters like the BBC demonstrate how infrastructures can be funded durably: statutory mandates, broad-based contributions, and independent governance secure both resilience and accountability (Booth 2020). Digital infrastructures could adopt similar logics—mandatory levies on commercial beneficiaries, redistributed via independent maintenance trusts.[11] Utilities are stabilised through statutory mandates, tariffs, and universal service obligations. Each of these approaches shows how permanence can be built into resourcing architectures—lessons ODI must adapt. From a global governance perspective, future architectures should address not only efficiency but also equity and sovereignty—ensuring that contributions and voice are distributed, and that open infrastructures remain transparent and resistant to capture by corporate or state actors. Debates on digital sovereignty cut across these concerns: e.g. the EU's Cyber Resilience Act frames open source within security and liability regimes, while UN-led initiatives designate open source as digital public goods for global development.

Resourcing is part of infrastructure: How we fund and organise ODI will shape its form and fate. Building public-interest resource architectures means aligning use with responsibility and embedding public value into durable institutions. Like roads or water systems, ODI is invisible until it fails; yet it is indispensable. Without systemic reform, fragility will persist. With it, digital commons can be secured as resilient, open, and democratic infrastructure for the twenty-first century.

As with ecological commons, sustainability rests not on ownership but on participation and shared stewardship. The challenge is not only financial but institutional: how to design cycles of action and transaction that regenerate rather than exhaust, that bind rather than fragment, and that embed digital infrastructures in the social contract.

11 See: https://ftw.fund/report.html for the browser ecosystem.

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17. Open Digital Infrastructures for Democratic Resilience and Economic Sovereignty

Leonhard Dobusch and Maximilian Heimstädt

Six Theses and Three Steps

Thesis 1: Digital resilience and sovereignty require open infrastructures. Proprietary infrastructures create dependencies. Only open standards, open protocols, and free software can ensure democratic and economic capacity for action in the long term.

Thesis 2: Decentralisation is empowerment. Open digital infrastructures enable freedom of choice, interoperability, and self-organisation. They break up the concentration of power in the platform economy and empower users and communities.

Thesis 3: The problem is not overuse, but provision. Open digital infrastructures are digital commons that cannot be 'consumed'—their bottleneck lies in development, maintenance and sustainable financing.

Thesis 4: The state is responsible for supporting digital public services. Like roads or electricity grids, open digital infrastructures are part of essential public services. Public funds and regulation must be used to specifically promote their development and maintenance.

Thesis 5: Governance requires socialisation. Following the example of public institutions (broadcasting, science), pluralistically controlled

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governance structures are needed. Such new forms of governance need to ensure the independence, public welfare orientation and sustainability of open digital infrastructures.

Thesis 6: New institutions for open digital infrastructures are possible. Public infrastructure funds, mandatory contributions in public digital budgets and new legal forms for digital commons can permanently anchor open digital infrastructures as a cornerstone of a democratic digital future.

In the following, we will substantiate these six theses and explain in three steps why (1) open digital infrastructure must be understood as a means of democratic and economic self-empowerment, (2) what tasks this entails for state-funded and other publicly funded institutions, and (3) why it makes sense to consider public social ownership as a sustainable form of governance for open digital infrastructures.

1. Open Digital Infrastructure as Economic and Democratic Self-Empowerment

Without digital infrastructures, social participation is hardly conceivable today. Whether in communication, education, science, business, or political participation—functioning digital networks, platforms, and applications are a prerequisite for a self-determined life. However, many of today's most important digital infrastructures are proprietary, centralised and in the hands of a few monopolistic corporations. Companies such as Alphabet, Meta, Amazon, and Apple control these central platforms, interfaces, and algorithms. This situation poses a growing concern for social participation, democratic resilience, and economic sovereignty.

This problem became particularly apparent when Elon Musk took over Twitter (now X) and has since been exploiting it for purposes of political propaganda. Here, the threat to democracy and open society posed by a commercialised, centralised digital infrastructure—which for many had previously been theoretical at best—became a dystopian reality. However, the takeover and propagandistic use of digital communication spaces is only the extreme case of systemic dependence on proprietary infrastructures. Even without explicit abuse, as in the case of Musk, the monopolistic dominance of centralised and profit-oriented

digital infrastructures leads to negative externalities for democratic societies (Bollier 2002; Doctorow 2020; Srnicek 2017; Zuboff 2022).

This problem is not limited to social media platforms, but it is particularly evident in this type of infrastructure: the algorithms of monopolistic, proprietary social media platforms, which are primarily profit-oriented, and reinforce polarisation and emotionalisation, thereby jeopardising democratic discourse. On the other hand, strong network effects combined with profit extraction strategies make it difficult for others to develop sustainable (media) business models based on these platforms. Doctorow (2023) refers to this problem as the 'enshittification' of proprietary digital infrastructures. For some time now, geopolitical tensions have also been adding to this already very complex problem involving digital infrastructure, democratic resilience, and economic sovereignty. This makes Europe's dependence on US and, increasingly, Chinese platforms a fundamental social risk (Floridi 2020). Due to this multitude of problems with proprietary digital infrastructures, questions about their democratic control, transparency, and sustainable provision are becoming the focus of public debate.

Open digital infrastructures represent a counter-model to this dominant approach (Lund and Zuckerfeld 2020; Lührsen et al. 2025). Like their proprietary counterparts, open digital infrastructures are fundamental technologies that serve as the basis for a wide range of downstream productive activities. The infrastructures are 'open' in the sense of their license terms, which allow anyone to use, modify and further develop them. Open digital infrastructures can only be open because they are designed as digital commons (Frischmann 2012), which are financed and maintained on a solidarity basis and are freely accessible to everyone (de Rosnay 2020; Bauwens et al. 2019). There are many examples of this, ranging from relatively 'invisible' infrastructures such as the MariaDB database, the Rust programming language and the OpenSSL security tool to very well-known infrastructures such as the free online encyclopaedia Wikipedia and the Fediverse as a network of open, protocol-based social networks. All these examples show that alternative models beyond commercial monopolies can scale and can be socially sustainable.

The strength of open digital infrastructures lies in their decentralised nature. Instead of a single company controlling servers, interfaces and

rules, free software and open protocols such as ActivityPub (the basis of many Fediverse services such as Mastodon, PeerTube, and Pixelfed) enable a distributed architecture. Users can operate their own instances or switch to alternative servers without losing access to social networks and thus also without losing the resources invested in building relationships. This decentralisation creates technological sovereignty at both the individual and collective levels—and thus the opportunity to emancipate oneself from monopoly-like structures.

The concentration of power in the platform economy, which is stabilised by network effects and lock-in mechanisms (e.g., WhatsApp, Facebook, YouTube), can thus be broken up by open standards. Interoperability and open interfaces mean freedom of choice: messengers such as Matrix or e-mail can continue to be operated independently as protocols, without having to accept the network effects of a monopolist. Self-empowerment thus arises from the structural possibility of becoming a provider, designer, or operator of digital infrastructure oneself.

The operation and use of communication infrastructure based on open software and protocols is nothing new for public institutions: universities routinely operate their own email servers for students and employees, and even the open internet itself has its origins in the interconnection of university computer systems (Grassmuck 2004).

However, the existence of these examples of open digital infrastructure should not obscure their fragility. Their social benefit stems from their openness. At the same time, this openness makes it difficult for the people who build, maintain, and develop these infrastructures to refinance their work. Also, because open digital infrastructures, as digital commons, do not suffer from classic overuse problems unlike natural resources (Dobusch and Quack 2011), the ongoing effort required to maintain them is often underestimated (Eghbal 2016). In order for open digital infrastructures to contribute to democratic resilience and economic sovereignty, continuous investment of time, knowledge, and money is necessary. This cannot be reliably ensured by traditional market mechanisms or by voluntary or selective philanthropic engagement.

2. Strengthening Open Digital Infrastructure as a Government Responsibility

The most important tasks of the state include not only the organisation of democratic participation and the provision of public services, but also the safeguarding of the foundation of common goods—education and science, mobility infrastructure, security apparatus—on which entrepreneurial innovation and productivity can flourish in the first place. In a world where both democracy and the economy depend on digital infrastructure, this task therefore also extends to digital commons in the form of open infrastructures.

In addition, government services already use open digital infrastructure in many areas. Government use alone increases the efficiency of public spending and promotes democratic resilience and economic sovereignty. However, usage alone does not solve the provision problem with open digital infrastructure. Above all, the public good nature of open digital infrastructure makes it difficult to finance the necessary development and maintenance work in a cost-covering manner (Eghbal 2016).

For this reason, the state cannot remain neutral on the issue of financing open digital infrastructure. Similar to transport and electricity networks or educational and research institutions, these are critical infrastructures whose sustainable protection cannot and must not be left solely—or even primarily—to private markets and voluntary and philanthropic contributions. Democratic institutions must understand open digital infrastructure as part of 'digital public services' (Daly et al. 2024; Schulz 2025).

At the same time, promoting open digital infrastructure, which often also constitutes communications infrastructure, is associated with potentially greater conflicts of interest than the provision of other government services: nationalisation or direct government operation would entail the risk of (party) politically motivated interference and encroachment, and would undermine the decentralisation of open digital infrastructures, which is desirable from a democratic perspective. The aim is therefore to strengthen these infrastructures without creating excessive dependency or even enabling state control.

Some approaches to public financing models for open digital infrastructure already exist. In 2024, for example, the Sovereign Tech Agency was founded in Germany as a new authority under the jurisdiction of the Federal Ministry of Economics. The Sovereign Tech Agency's mandate includes the financial and conceptual support of selected individuals and projects in the field of open digital infrastructure. In 2024, the agency had just under twenty million euros at its disposal for this task. To support open digital infrastructures, the Sovereign Tech Agency has developed various funding formats, ranging from commissioning specific activities in infrastructure projects to providing individual support to individual infrastructure 'maintainers' (Lührsen et al. 2025).

However, government responsibility does not only mean financial support, but also the creation of suitable regulatory frameworks. Open standards and interoperability must take precedence over proprietary, closed systems. One example is the EU's Digital Markets Act, which imposes interoperability obligations on gatekeepers—albeit only to a limited extent so far (Peacock 2020). Political decisions such as these can make a decisive contribution to ensuring that open digital infrastructures do not remain niche projects but represent a viable alternative to monopolistic platforms.

3. Public Socialisation as a Sustainable Form of Governance

In order for open digital infrastructures to reliably contribute to democratic resilience and economic sovereignty, their governance must also be reconsidered. On the one hand, it is decentralised control by communities—i.e. the absence of a centre guided by particular interests—that enables open digital infrastructures to contribute to sovereignty (Schrape 2015). When states rely on infrastructures that cannot be 'hijacked,' this promotes their own sovereignty. On the other hand, such community governance is by no means immune to external influences, such as from dominant technology companies. For example, there are a number of open digital infrastructures whose volunteer contributors are employed by large technology corporations (O'Neil et al. 2024). Although the involvement of corporations solves the provision problem of open digital infrastructure, there is a risk that the interests

of the corporation will strongly influence the development path of the infrastructure through the paid members of the community.

With the growing importance of open digital infrastructure for social participation, new governance models are needed that institutionalise collective responsibility (Frischmann 2012). Public structures such as those found in public service media (e.g., ARD/ZDF, BBC) or in science (universities, academies) offer possible starting points and points of reference: there, public funding and accountability, as well as legally enshrined stakeholder participation, ensure a focus on the common good without being subject to the short-term logic of private returns or state arbitrariness (Dobusch 2022). Such a public-law framework for open digital infrastructure could create forms of collective and public socialisation that are democratically legitimised but at the same time largely insulated from party political influences.

Models such as decentralised staffing of public supervisory bodies by stakeholder organisations in combination with random democratic selection procedures among users could ensure pluralistic representation on supervisory bodies. When it comes to financing, there are also examples of institutional solutions that sustainably secure common goods in the form of open access infrastructures in science (e.g. OpenAIRE). For open digital infrastructure, this would mean stable structures in which the financing, further development, and governance of the infrastructure are anchored as a collective task—supported primarily by public funds, civil society, and users alike.

Robust institutional arrangements are needed to ensure that open digital infrastructures do not remain dependent on selective funding or voluntary commitment. A first step could be to establish a public fund for open digital infrastructures that would ensure the long-term development and maintenance of central open-source projects and open standards—independent of legislative periods. This fund could be financed by a low levy on digital sales, platform advertising or telecommunications fees.

To ensure that funds are allocated on the basis of criteria that serve the common good rather than day-to-day political considerations, the governance structure of such a fund is of crucial importance. Similar to pluralistic bodies in the public sector, a multi-stakeholder supervisory body should be established in which representatives from civil society,

academia, the public sector and user communities participate on an equal footing. This will ensure that open digital infrastructures are not monopolised by individual interests but are subject to broad democratic control.

In addition, a mandatory share of public funds for commons infrastructures would be conceivable: a certain percentage of all government digital budgets—for example, in the context of research funding, digitisation strategies or administrative modernisation—could be reserved for open standards, open-source base projects and interoperable protocols. This would prevent public funds from indirectly reinforcing dependence on private-sector monopolies and instead promote the development of sustainable alternatives in a targeted manner.

Finally, consideration should be given to whether open digital infrastructures can also be secured by new legal forms that fall between associations, foundations and public enterprises. This could lead to the creation of 'digital commons cooperatives' or 'public infrastructure facilities' that are explicitly mandated to provide open, decentralised infrastructures in the public interest. This would enable the institutional landscape to meet the specific requirements of open digital infrastructures. Thus, digital commons could be permanently established as a cornerstone of a democratic society.

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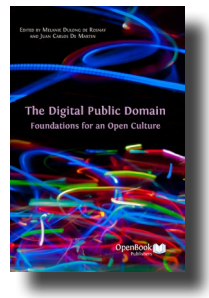

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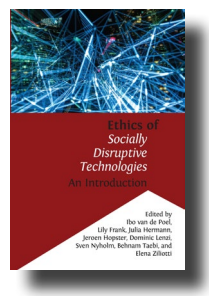

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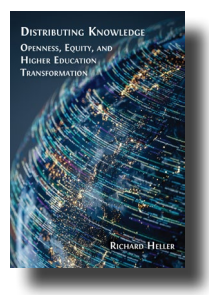

The Politics of Open Infrastructures

Power, Governance, and Justice in Digital Knowledge Practices

Edited by Katja Mayer, Astrid Mager and Renée Ridgway

This volume examines how openness is designed, governed, contested and lived in contemporary digital knowledge infrastructures. From open source software and internet standards, to citizen science platforms, public sector data systems and alternative computing practices, the book shows that infrastructures are never neutral technical backbones. They are deeply political arrangements that embed values, distribute power and shape whose knowledge counts.

Bringing together scholars from science and technology studies, critical data studies, media studies, organisation studies, arts-based research and political sociology, this edited volume explores openness as an ongoing socio-technical process rather than a fixed ideal. The book moves from the partial openness of early Internet standards and free and open source software, through contested practices of opening government data and public infrastructures, to struggles over inclusion and governance in scholarly and cultural knowledge infrastructures. This is followed by community-driven experiments in care, repair and alternative openness and concludes with forward-looking contributions on how to keep infrastructures open for research, how to fund infrastructures as digital commons and how to mobilise open infrastructures for democratic resilience and economic sovereignty.

The contributions trace how principles such as accessibility, transparency, participation and collective stewardship are enacted in practice—and how they are challenged by commercial capture, asymmetries of expertise, cultural governance and geopolitical inequalities. Across theoretical chapters and rich empirical case studies, the book investigates the governance of open infrastructures, the politics of alternative technological arrangements and struggles for epistemic justice within knowledge systems.

By foregrounding power relations, ethical tensions and questions of responsibility, this book rethinks openness as a site of political negotiation rather than a technical solution. The volume offers critical insights for researchers, policymakers, engineers and civil society actors concerned with digital commons, democratic governance and the future of open knowledge infrastructures in increasingly contested political and technical environments.

A companion website, openinfrastructures.net, extends the volume through author interviews, supplementary materials and additional resources that document the making of the book and provide further insights into the debates on governing, sustaining, and contesting open digital knowledge infrastructures.

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